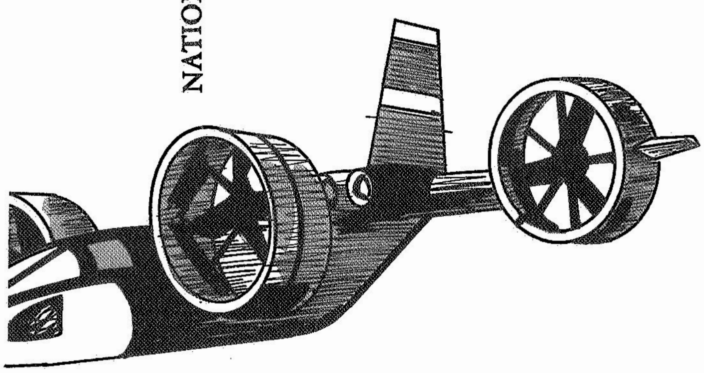
16th

SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



TO THE CONGRESS OF THE UNITED STATES:

I am transmitting today the Sixteenth, Seventeenth, and Eighteenth Semi-Annual Reports of the National Aeronautics and Space Administration covering the period between July 1, 1966 and December 31, 1967.

The events recorded here are both tragic and encouraging; sobering and inspiring.

The eighteen-month period saw success and failure and then success again as a proud agency moved forward with renewed determination.

The Gemini missions were completed; Lunar Orbiters I and II transmitted thousands of clear pictures of the moon; new communications and meteorological satellites were orbited.

Then came tragedy. Three brave American astronauts were killed in the Apollo fire.

Initially stunned, NASA then went to work to overcome the flaws in the Apollo system. Soon, impetus was restored to this crucial part of our space effort. Other great space achievements followed such as the Apollo 4 flight.

I commend these reports to your attention. They contain, I believe, concrete evidence that NASA is moving forward, and that America is contributing mightily in the worldwide effort to conquer space for the benefit of all mankind.

THE WHITE HOUSE,

Oct 11 1968

Sixteenth SEMIANNUAL REPORT TO CONGRESS

JULY 1 - DECEMBER 31, 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

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THE PRESIDENT

The White House

OCTOBER 7, 1968

DEAR MR. PRESIDENT:

I am pleased to submit to you this Sixteenth Report of the National Aeronautics and Space Administration for transmittal to Congress in accordance with section 206(a) of the National Aeronautics and Space Act of 1958. The report covers the months July through December 1966.

This period was a very satisfying one. It saw the Gemini program brought to an eminently successful conclusion with the Gemini X, XI, and XII flights. Space sciences programs made unprecedented progress. Lunar Orbiters I and II transmitted thousands of clear pictures of the moon. Intelsat II was orbited for the Communications Satellite Corporation, extending the network of commercial communications satellites and linking Hawaii with continental United States. The first Applications Technology Satellite carried advanced meteorological and communications experiments into orbit.

These successes and the other progress recorded in this report represented substantial forward steps in the development and demonstration of our national capabilities in aeronautics and space.

Respectfully yours,

JAMES E. WEBB

Administrator

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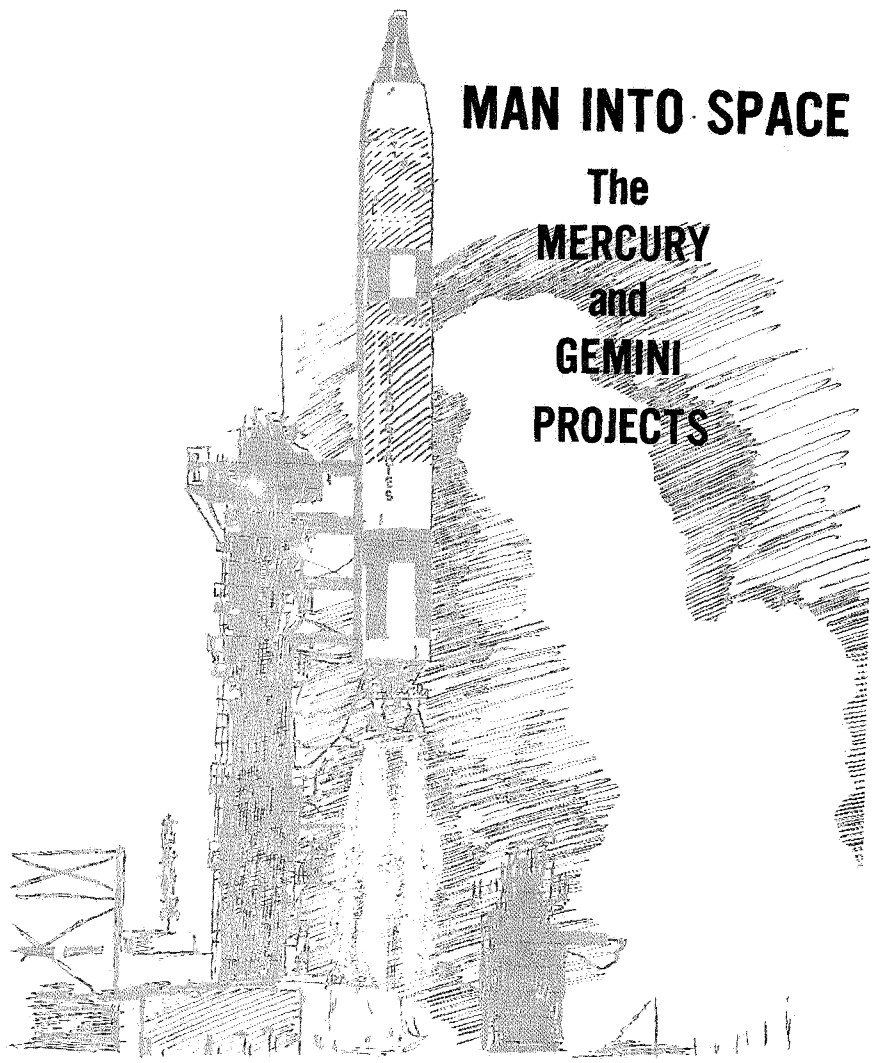
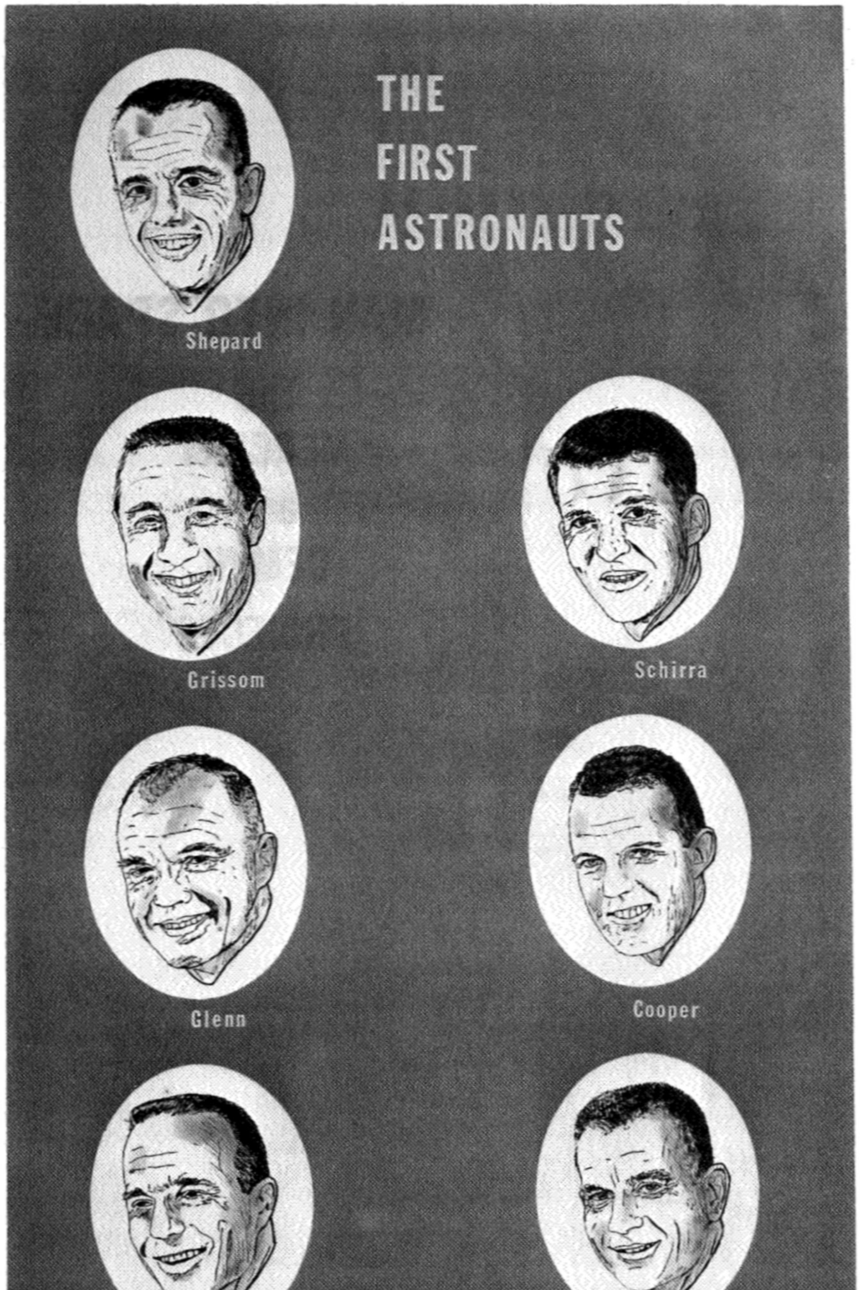



THE
FIRST
ASTRONAUTS
Shepard
Grissom
Schirra
Glenn
Cooper
Carpenter
Slayton

MAN INTO SPACE

The Mercury and Gemini Projects

On October 7, 1958, the National Aeronautics and Space Administration initiated the nation's first manned space flight project—Project Mercury. On November 15, 1966, NASA concluded the second manned space flight program when the Gemini XII spacecraft splashed down in the Atlantic Ocean.

Between these two dates, nineteen American astronauts completed sixteen manned space flights; logged almost 2000 hours in space; carried out extravehicular activity; conducted rendezvous and docking experiments; and proved that man can and will explore space, just as he has explored the lands and seas of the earth.

MERCURY

Project Mercury's objectives were to place a manned spacecraft in orbital flight around the earth, to investigate man's performance capabilities and his ability to function in the environment of space, and to safely recover both the man and the spacecraft. These objectives followed specific studies conducted before and during 1958, indicating that manned space flight was indeed feasible. The basic guidelines for Project Mercury included using existing technology and off-the-shelf equipment, following the simplest and most reliable approach to system design, using an existing launch vehicle to orbit the spacecraft, and conducting a progressive and logical test program. Among the spacecraft requirements were a reliable launch-escape system, manual controls, a retrorocket braking system, a zero-lift body design, and a capability for water landing.

In January 1959, NASA began selecting the first astronauts. Seven were selected: Alan B. Shepard, Jr., a Navy lieutenant commander; Virgil I. Grissom, an Air Force captain; John H. Glenn, Jr., a Marine lieutenant colonel; M. Scott Carpenter, a Navy lieutenant; Walter M. Schirra, Jr., a Navy lieutenant commander; L. Gordon Cooper, Jr., an Air Force captain; and Donald K. Slayton, an Air Force captain. In April, the astronauts reported to the Space Task Group, Langley Field, Virginia, and began a two-year program of group training in five major areas: basic astronautical science, systems, spacecraft control, environmental familiarization, and egress and survival.

In April 1961, a special preflight preparation program was conducted for each astronaut and his backup for the flight. The remaining five astronauts took part in development and operational activities and participated in training programs to maintain proficiency. The specific preflight preparation programs involved pilot-spacecraft integration, systems training, developing and practicing the mission flight plan, training with flight controllers, and medical and physical preparation.

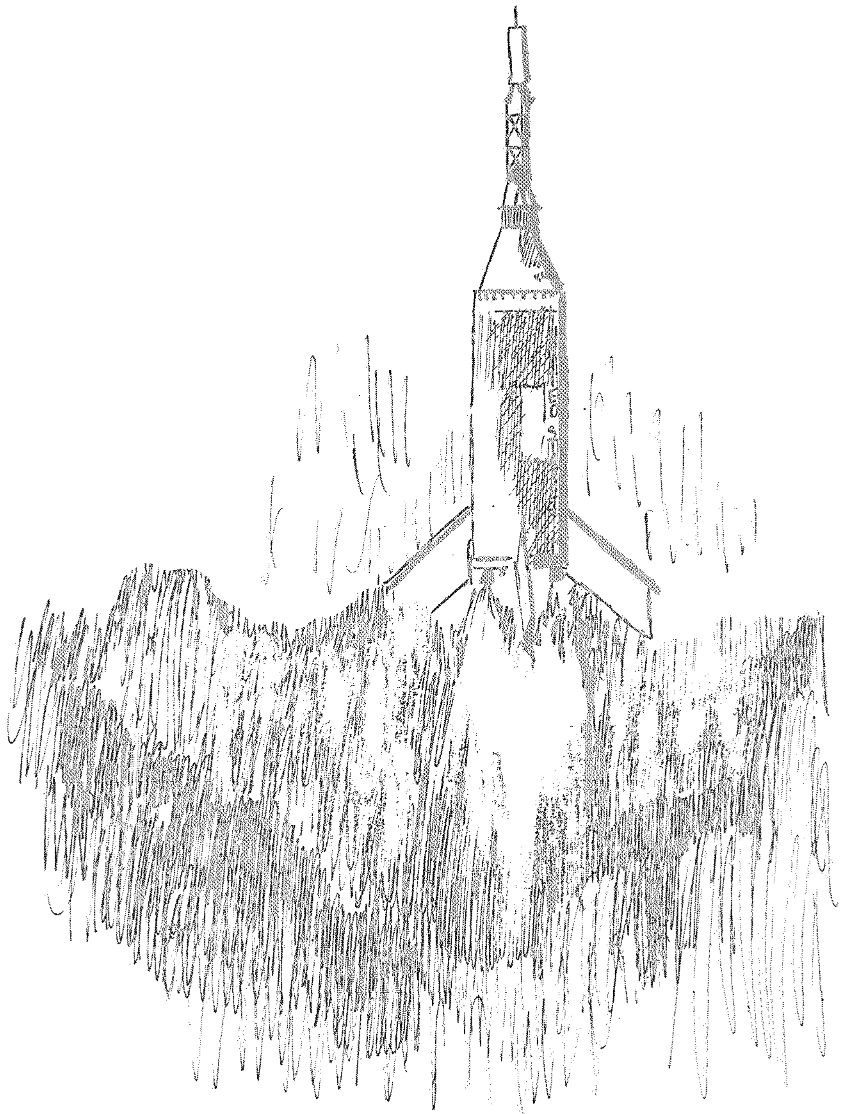
Although the original Project Mercury flight test plan called for twenty-seven flights, only twenty-four were actually accomplished as a result of modifications, eliminations, and additions. Passengers were carried on these flights:

Little Joe 2, December 4, 1959: This test, conducted at Wallops Island to check the high-altitude performance of the Mercury escape system, carried a rhesus monkey, "Sam," as test subject. All test objectives were met and both the spacecraft and passenger were recovered.

Little Joe 1–B, January 21, 1960: This test at Wallops Island evaluated the escape system under high aerodynamic load, carrying a second rhesus monkey, "Miss Sam," as the test subject. The spacecraft and occupant were successfully recovered.

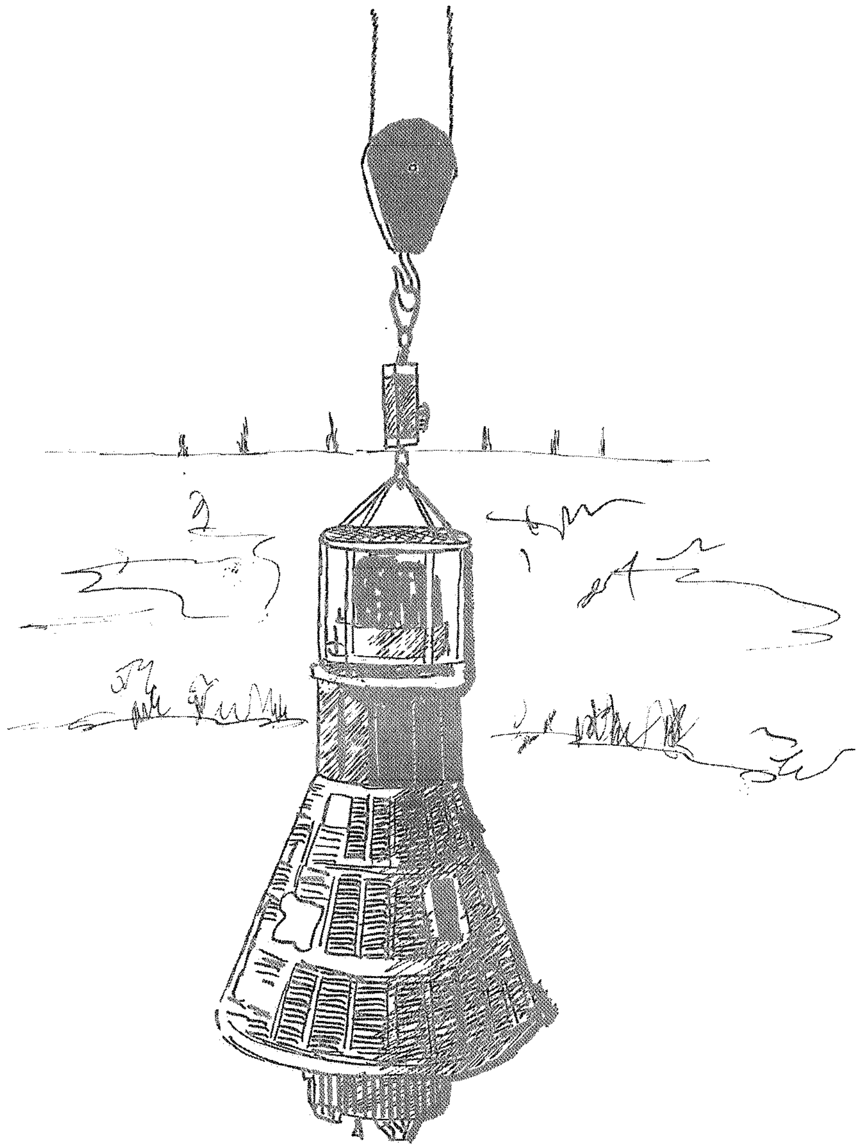
Mercury-Redstone II (MR–2), January 31, 1961: This flight from the Atlantic Missile Range shot a Mercury capsule containing a chimpanzee named "Ham" to an altitude of 157 miles and a distance of 418 miles downrange. The capsule and its life-support equipment functioned well, but the flight was 42 miles higher and 125 miles further than programed. "Ham" was recovered in good health.

Mercury-Redstone III (MR–3), May 5, 1961: This was the first manned suborbital flight in Project Mercury. At 9:34 a.m. (all times are Eastern Standard), a 78,000-pound-thrust Redstone lifted off from Pad 5 at Cape Kennedy, carrying Astronaut Alan B. Shepard, Jr., in the *Freedom 7* spacecraft. The 2,855-pound capsule landed 302 miles downrange in the Atlantic Ocean 15 minutes and 22 seconds later, after reaching a peak altitude of 116.5 miles and a top velocity of 5,134 mph. Astronaut Shepard experienced 5 minutes and 16 seconds of weightlessness and maximum reentry forces of 11 g's, carried out all his tasks as assigned, and suffered no adverse physiological effects from his flight. The objectives of this flight were to familiarize man with brief space flight, including liftoff, powered flight, weightlessness, reentry



and landing; to evaluate man's ability to perform useful functions; and to study physiological reaction in space flight. The flight was also the first test of Mercury systems with an astronaut aboard.

Mercury-Redstone IV (*MR–4*), July 21, 1961: The second successful Project Mercury manned suborbital flight was achieved with astronaut Virgil I. Grissom as pilot of the spacecraft *Liberty Bell 7*. Flight objectives were to confirm data obtained dur-



ing the first suborbital flight and to further test the Mercury capsule and its life-support and telemetry systems. The flight began with liftoff from Cape Kennedy at 7:20 a.m. The capsule reached an altitude of 118 miles and traveled 303 miles down the Atlantic Missile Range, landing in the planned recovery area at 7:35. In the course of the trip, Grissom experienced 5 minutes and 18 seconds of weightlessness. He visually confirmed such flight

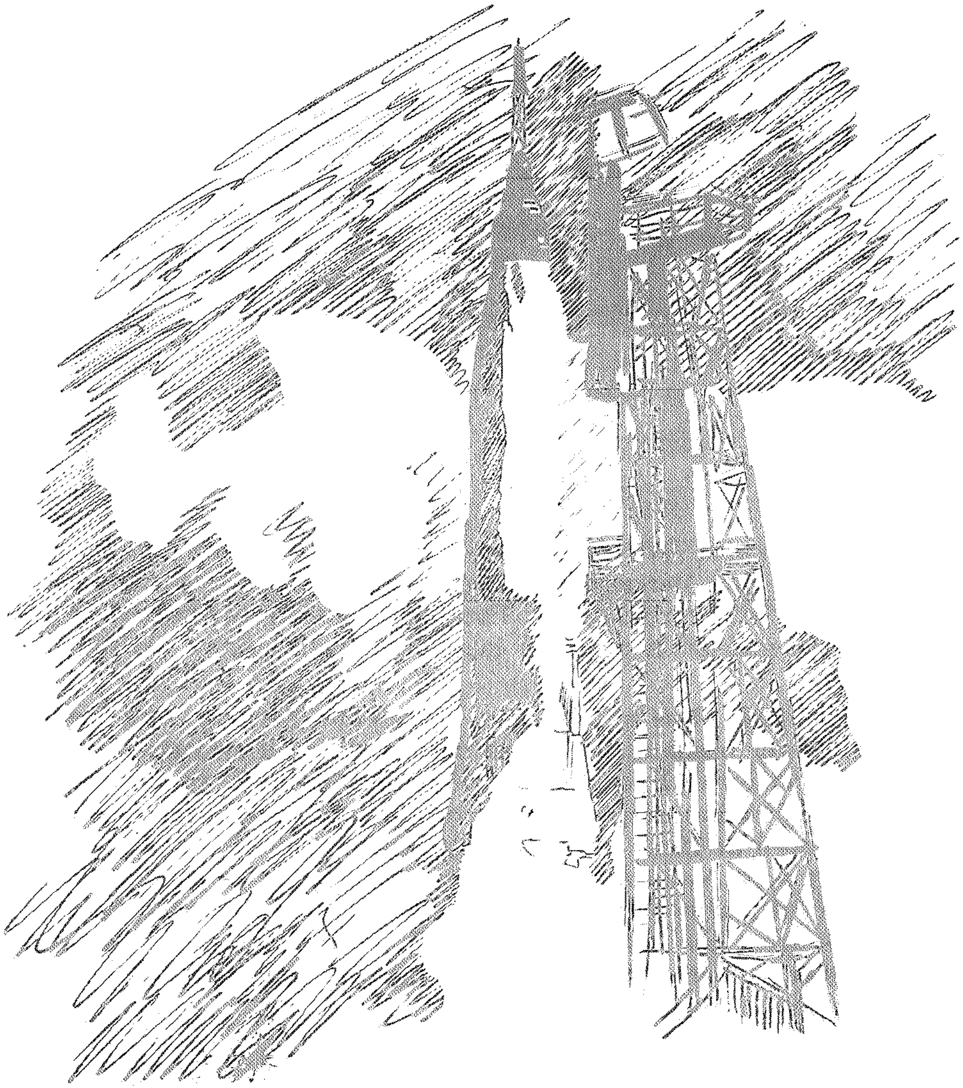
sequences as booster separation, jettison of retrorocket, and drogue and main parachute openings. Grissom successfully maintained altitude control with the manual control systems, manually triggered ignition of the retrorockets from the capsule, and exercised manual capsule-attitude control during the 22-second rocket firing which slowed the capsule for reentry. During descent and atmospheric entry, the capsule underwent a maximum deceleration force of 11 g's, which Grissom withstood without difficulty, making several voice communications during this period. Before the rescue helicopter could hook onto the capsule, the escape hatch was separated from the side of the capsule by a premature firing of its explosive bolts, and the capsule began to sink. Grissom swam away from it and was rescued by a second helicopter 4 minutes later. All efforts to save the capsule failed, and it sank in water too deep for salvage operations.

Mercury-Atlas V (MA–5), November 29, 1961: This was planned as a three-orbit flight to simulate manned space flight conditions as closely as possible by sending a chimpanzee into orbit in a Mercury capsule. Preparations for the flight followed precisely the routine set for a manned flight. The launching took place at 10:08 a.m. During the first orbit, all spacecraft systems functioned properly, and "Enos," the chimpanzee, carried out his four main tasks, which involved a series of lever-pulling exercises designed to indicate any effects of weightlessness and the stresses of space flight. During the second orbit, the capsule's roll control system and cooling system began to malfunction, and Mercury Control Center decided to terminate the mission after the first two orbits. The capsule made a normal reentry and the landing occurred at about 1:18 p.m. in the planned recovery area. "Enos" suffered no ill effects from the flight.

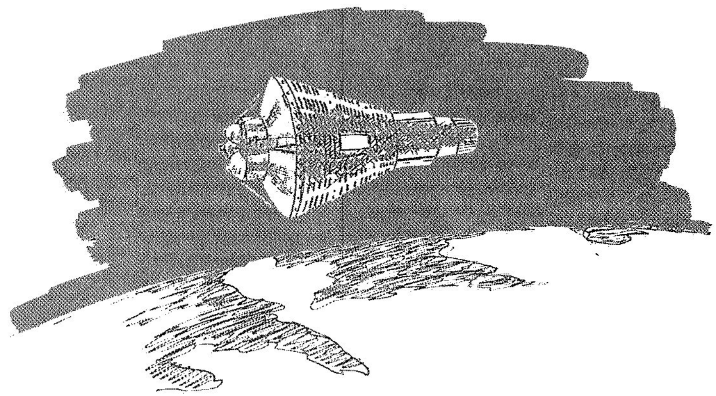
Most of the test objectives of the MA–5 flight were accomplished. A detailed post-flight analysis of the spacecraft, booster, and tracking network operation indicated that the Mercury-Atlas system was ready for manned orbital flight and that the mechanical problems which developed during the second orbit would have been corrected if a human astronaut had been aboard. At the conclusion of this flight, NASA announced that Astronaut John H. Glenn, Jr., had been selected as pilot for the first manned orbital Mercury mission.

Mercury-Atlas VI (MA–6), February 20, 1962: The major objectives of the first Project Mercury manned orbital flight were to investigate man's capabilities in the space environment and to test both spacecraft and supporting systems. The flight met all test objectives and was therefore completely successful.

Liftoff, launch, and insertion into orbit were perfect. The



apogee of orbit was about 162 miles; perigee was about 100 miles. The actual sequence, flight, and tracking times were all within seconds of those planned. During the flight, Astronaut Glenn, in the *Friendship 7* capsule, experienced weightlessness for 4.6 hours with no adverse effect on his performance and made visual and photographic observations of the earth, clouds, horizon, and stars. The flight completed three full orbits before the spacecraft returned to earth in the planned recovery area, 700 miles southeast of Cape Kennedy, at 2:43 p.m. The capsule landed 5 miles from the destroyer U.S.S. *Noa* and was quickly recovered from the water in good condition.



Mercury-Atlas VII (*MA–7*), May 24, 1962: In the second orbital flight of Project Mercury, the *Aurora 7* spacecraft was piloted by Astronaut M. Scott Carpenter. The flight achieved its objective of continued evaluation of man's capabilities in the space environment.

Liftoff took place at 7:45 a.m. from Cape Kennedy, and the entire power phase of flight was normal, with all systems functioning perfectly. Apogee and perigee of the orbit were about 167 and 100 miles, respectively. After three full orbits, the spacecraft landed at 12:31 p.m., 250 miles downrange of the planned recovery area. Astronaut Carpenter was sighted by a searchplane about 1 hour after impact, and three hours after he landed, helicopters from the U.S.S. *Intrepid* picked him up. The spacecraft was recovered by the destroyer *U.S.S Pierce*, approximately 6 hours after impact.

Mercury-Atlas VIII (*MA–8*), October 3, 1962: The third orbital flight in Project Mercury was that of astronaut Walter M. Schirra, Jr., in the *Sigma 7* spacecraft. Its major objective was to evaluate the performance of the manned spacecraft system in a six-orbit mission. Liftoff occurred at approximately 7:15 a.m. and launch and insertion into orbit were perfect. Apogee and perigee of orbit were 176 and 100 miles, respectively. The flight completed nearly six full orbits, and landed in the planned recovery area near Midway Island in the Pacific Ocean at 4:28 p.m.

During the flight, Schirra experienced nearly 9 hours of weightlessness, carried out extended periods of drifting flight, checked out the spacecraft control system periodically, took

photographs of terrestrial features, performed visual yaw-alignment experiments, and ate and drank. Retrofire occurred on time, and the spacecraft landed about 4 miles from the aircraft carrier *Kearsarge*. The carrier picked up the spacecraft, with the pilot still in it, 40 minutes after landing. This 9-hour-and-13-minute test of man's capabilities in the space environment and of the engineering concepts of the spacecraft and supporting sys-

tems was completely successful, and thus provided the added experience needed for the next flight in the Mercury-Atlas series—the "One-Day Mission."

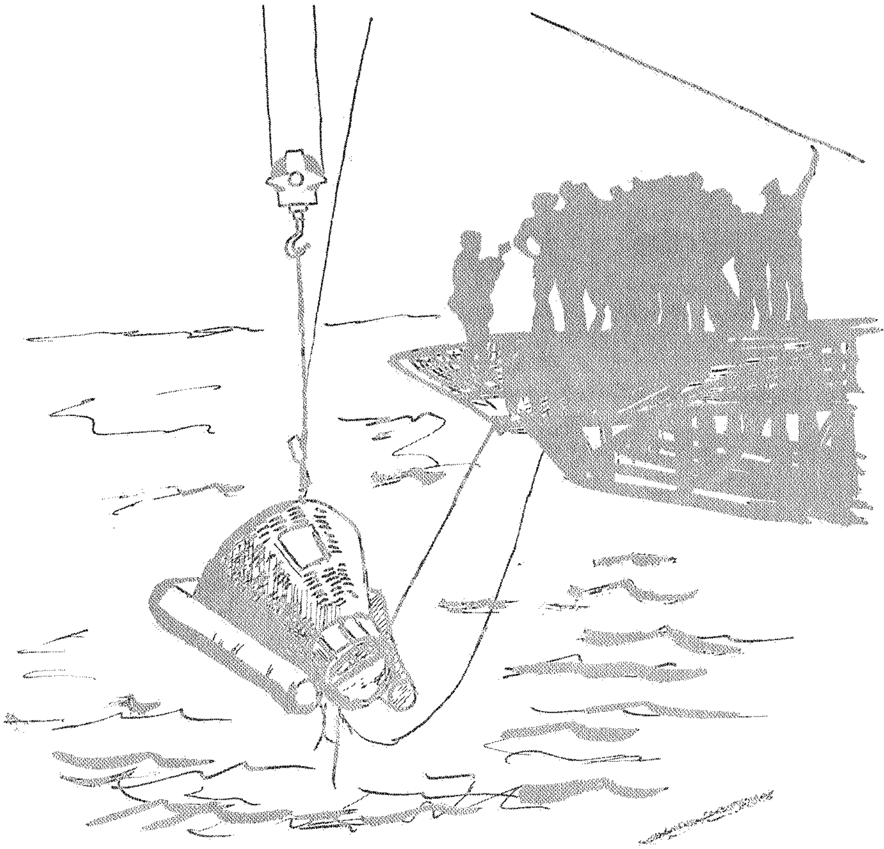
Mercury-Atlas IX (MA-9), May 15–16, 1963: The fourth manned orbital flight in Project Mercury—that of astronaut L. Gordon Cooper, Jr., in the *Faith 7* spacecraft—was an extension of Project Mercury for which a "One-Day Mission" spacecraft (modified Mercury) was used. The major objective of this mission was to evaluate the effects of weightlessness and extended orbital flight on man, and in this respect the flight was highly successful, meeting all test objectives. The mission covered 22 orbits with a total flight time of 34 hours, 19 minutes, 49 seconds. The launch system inserted the spacecraft into a nearly perfect orbit, with liftoff at approximately 8:04 a.m. The spacecraft systems performed as planned until the 19th orbit when difficulties developed in the automatic control system.

Astronaut Cooper manually controlled his spacecraft throughout the remainder of the mission, and his control of the spacecraft during retrofire and reentry was excellent, for he landed within 4 miles of the predicted landing point near Midway Island in the Pacific at 6:24 p.m. the day after launch. The aircraft carrier U.S.S. *Kearsarge* retrieved the spacecraft with the pilot still inside, approximately 35 minutes after landing. He slept for about 7½ hours during the mission, and his general state of health was good upon recovery; a weight loss of 7 pounds was attributed to temporary dehydration.

Scientific and engineering investigations conducted during the flight comprised aeromedical and photographic studies, radiation and spacecraft temperature measurements, and communications and visibility experiments.

From Project Mercury, the United States learned how to design, build, and test spacecraft; how to adapt launch vehicles for safe and reliable manned flight; how to operate a worldwide network of radio and radar to track the spacecraft and remain in communication with the pilot; how to recover spacecraft from the ocean; how to select and train astronauts; and how to develop and operate life support systems, pressure suits, and biomedical instrumentation systems.

The objectives of Project Mercury, as laid out in 1958, were to take the first step in the manned exploration of space, to determine man's capabilities in space, and to develop the foundation for the technology of manned space flight. These objectives were more than met, and the way was paved for the next step—the Gemini missions.



GEMINI

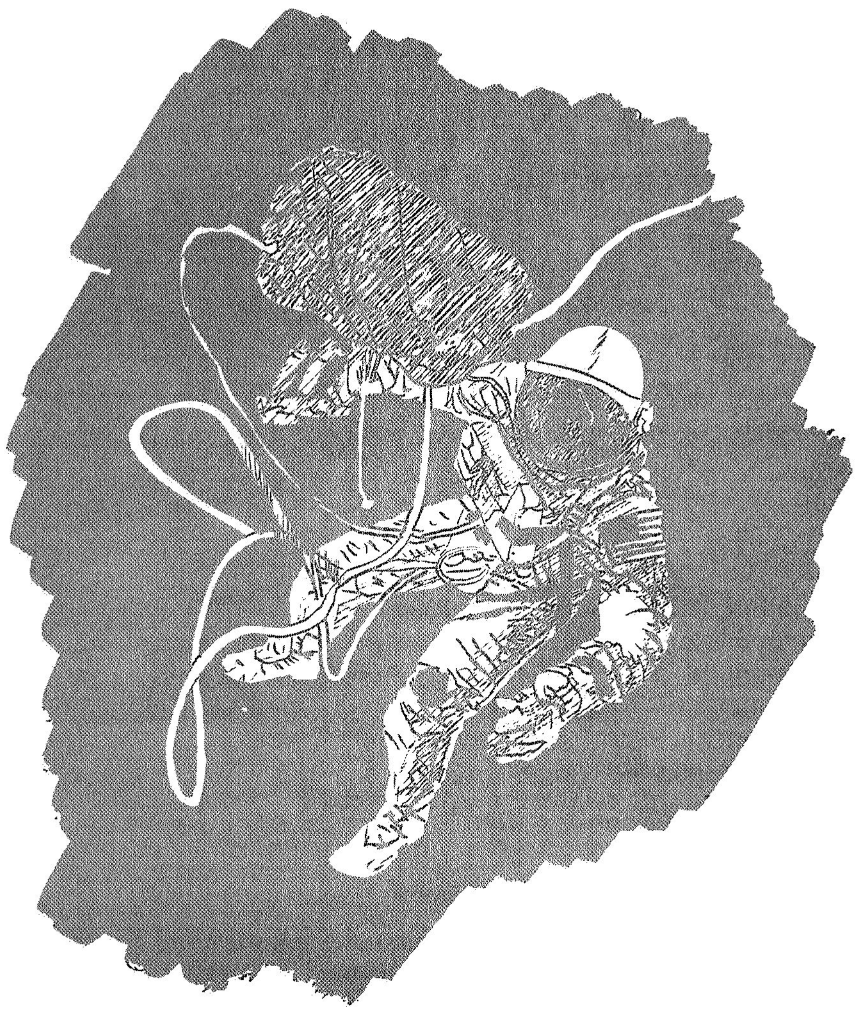
On December 7, 1961, the National Aeronautics and Space Administration announced a plan to extend the existing manned spaceflight program by developing a two-man spacecraft. The new program, officially designated Gemini on January 3, 1962, was conceived after it became evident that an intermediate step was required between Project Mercury and the Apollo Program. Thus, Gemini came into being and was assigned the following major objectives:

To subject two men and supporting equipment to long duration flights—a requirement for projected later trips to the moon or deeper space;

To effect rendezvous and docking with other orbiting vehicles.

To perfect methods of reentry and landing the spacecraft at a preselected point on land; and

To gain additional information about the effects of weightlessness on crew members and to record their physiological reactions during long duration flights.



Another objective, added during the course of the program, was to maneuver a spacecraft and its target vehicle in the docked configuration, using the propulsion system of the target.

A study of the flight results of the twelve Gemini missions reveals the success of the program. All the major objectives were met, except the land landing, which was canceled in 1964. However, the precision control necessary to achieve that objective was demonstrated.

All Gemini launches took place at the Kennedy Space Center.

Gemini I: The first Gemini flight, on April 8, 1964, was unmanned with no recovery planned. Primary objectives of the mission were to check the overall dynamic loads on the structural shell spacecraft during the launch phase and to demonstrate the

structural compatability of the spacecraft and the Gemini launch vehicle. The spacecraft was placed in an elliptical orbit with a perigee of 99.6 miles and an apogee of 204 miles. It was not separated from the second stage of the launch vehicle and burned up when it reentered the earth's atmosphere during the 64th orbit somewhere over the South Atlantic. The flight achieved all its major objectives and also demonstrated the performance of the tracking network, provided training for flight controllers, and verified the operational capabilities of the prelaunch and launch facilities.

Gemini II: Gemini II, the second and final unmanned flight in the Gemini Program, was a suborbital flight launched January 19, 1965, at 9:04 a.m., and completed 18 minutes and 16 seconds later.

Primary objectives were to demonstrate the adequacy of the reentry module's heat protection equipment during a maximum reentry heating rate, to demonstrate the structural integrity and capability of the spacecraft from lift-off through recovery, and to demonstrate satisfactory performance of the spacecraft systems. Sequencers simulating crewmen were installed on seat pallets. During the brief flight, Gemini II attained an altitude of 99 miles and traveled 2,125 miles down-range. It was recovered by the aircraft carrier U.S.S. *Lake Champlain* in the mid-Atlantic 108 minutes after lift-off. The mission served as the final flight qualification of the total Gemini space vehicle before manned flights.

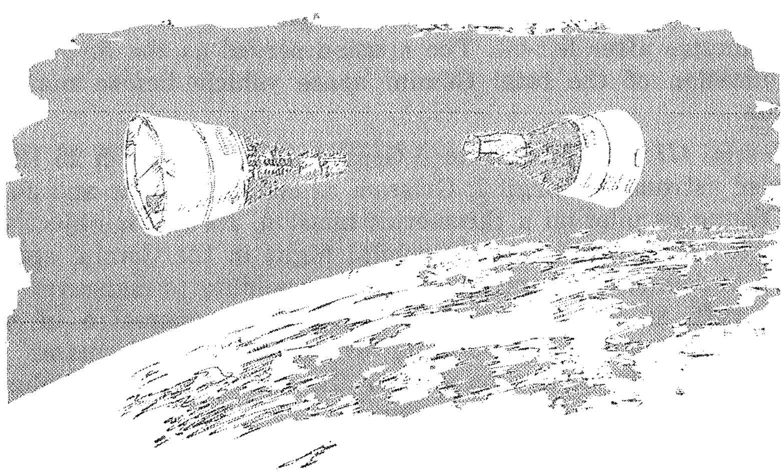
Gemini III: The first manned Gemini flight, on March 23 1965, carried astronauts Virgil I. Grissom as command pilot and John W. Young as pilot on a three-orbit mission. Its major objectives were to demonstrate manned orbital flight in the Gemini spacecraft, to demonstrate and evaluate the capability to maneuver the spacecraft, to demonstrate and evaluate the operation of the worldwide tracking network, to evaluate the performance of spacecraft systems, and to recover the spacecraft and evaluate the recovery system.

Gemini III was launched at 9:24 a.m., on a flight lasting 4 hours, 52 minutes, and 31 seconds. The astronauts conducted an orbital maneuver over Texas during the first orbit, changing the orbital path of a manned spacecraft for the first time. They also fired the forward and aft thrusters in a series of maneuvers to make minute changes in the orbital path. This activity occurred over the Indian Ocean during the second orbit. The maximum height reached during the flight was 140 miles; the lowest point, 85.2 miles. The spacecraft landed about 50 miles from the predicted landing point at 2:16:31 p.m., the crew was recovered at

3:28 p.m., and the spacecraft was picked up at 5:03 p.m. The prime recovery ship was the U.S.S. *Intrepid*

Gemini IV: The Gemini IV four-day (June 3–7, 1965) mission had these major mission objectives: to demonstrate an devaluate the performance of spacecraft systems for approximately four days in space; to evaluate the effects of prolonged exposure to the space environment in preparation for longer missions; to demonstrate the feasibility of extravehiular activity; and to conduct 11 experiments.

The flight crew—astronauts James A. McDivitt and Edward H. White, II—was the first American crew to open a spacecraft hatch and have one member engage in extravehicular activity. The hatch was open for 36 minutes, and White was outside the spacecraft for 22 minutes of that time. Gemini IV attained an apogee of 184 miles and a perigee of 99 miles. Touchdown, in the western Atlantic, occurred after 97 hours, 56 minutes, and 12 seconds of flight at 12:12:12 p.m., approximately 50 miles from the prime recovery ship, the U.S.S. *Wasp*. The crew was recovered at 1:09 p.m. and the spacecraft at 2:28 p.m.

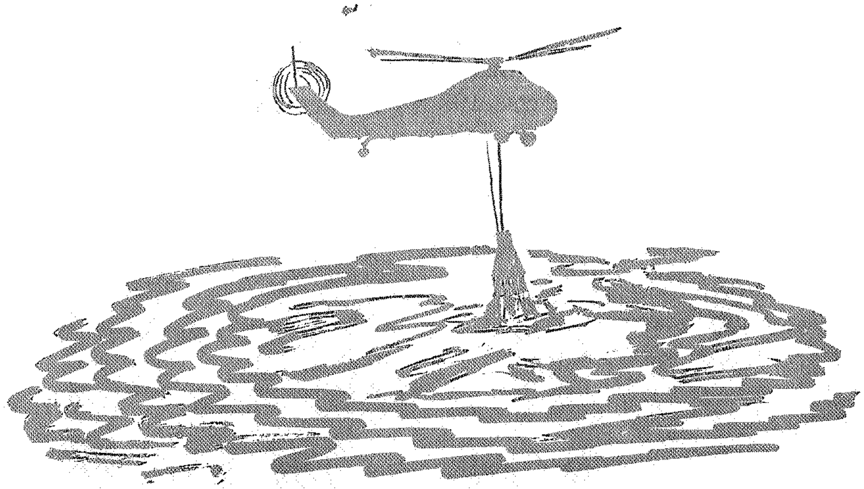


Gemini V: The Gemini V flight extended from August 21 through August 29, 1965. Astronaut L. Gordon Cooper, Jr., was the command pilot, and Astronaut Charles Conrad, Jr., served as pilot. Major mission objectives were to demonstrate and evaluate performance of the Gemini spacecraft for eight days; to evaluate the rendezvous guidance and navigation system, using the radar evaluation pod; and to evaluate the effects of prolonged exposure of the crew to the space environment. In addition to 17

experiments, Gemini V also carried fuel cells for electrical power —the first flight to do so.

After launch at 9:00 a.m., August 21, the flight went according to plan, but a rapid drop in pressure in the cryogenic storage tanks which supplied the fuel cells required that many of the planned activities be curtailed or abandoned. To simulate rendezvous with a "phantom Agena" target during the third day of the mission, Cooper and Conrad executed four maneuvers during two revolutions. Ground tracking indicated that the simulated rendezvous maneuver would have placed the spacecraft within three-tenths of a mile of the target.

Flight apogee was 217 miles, perigee 100 miles. Following retrofire, the spacecraft touched down in the western Atlantic approximately 90 miles short of the predicted impact point at 7:55:14 a.m., August 29. The crew was recovered at 9:26 a.m., and the spacecraft was picked up by the prime recovery ship, the U.S.S. *Lake Champlain,* at 11:50 a.m. The flight had lasted 190 hours, 55 minutes and 14 seconds.

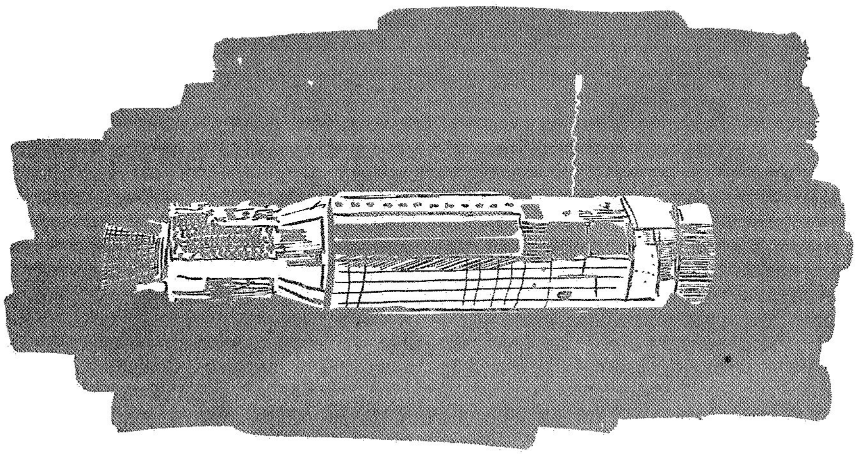


Gemini VI: Gemini VI was scheduled for launch on October 25, 1965. When the Gemini Agena Target Vehicle was launched at 10:00:04 a.m., the Gemini VI spacecraft was being readied for launch and the flight crew, Astronauts Walter M. Schirra, Jr., and Thomas P. Stafford, were inside the spacecraft and participating in the countdown. Six minutes and 16 seconds after target vehicle lift-off, a propulsion failure and subsequent breakup of the target vehicle occurred. The flight of Gemini VI was postponed and later rescheduled (as Gemini VI–A) to coincide with the Gemini VII mission.

Gemini VI–A: On December 12, 1965, command pilot Schirra and pilot Stafford were ready and waiting in the spacecraft as the countdown proceeded without interruption toward the scheduled lift-off. Ignition occurred on time, but the engines automatically shut down 1.2 seconds later. The crew correctly assessed the situation and determined that it was safe to remain in the spacecraft. Later it was found that a small electric plug in the tail of the launch vehicle had dropped out prematurely and that a plastic dust cover had blocked an inlet line of a gas generator. Either would have prevented lift-off.

The flight was rescheduled for December 15, and on that date Gemini VI–A was launched at 8:37:26 a.m. The crew had as their primary objective a rendezvous with the Gemini VII spacecraft during their fourth revolution. Other objectives were to conduct station keeping exercises with Gemini VII, to evaluate the reentry guidance capability of the spacecraft, and to conduct a limited number of experiments. Once in flight, Schirra completed the maneuvers necessary to enable Gemini VI–A to rendezvous with Gemini VII, 5 hours and 56 minutes after lift-off. Station keeping followed and lasted over five hours, during which time the two spacecraft were maneuvered so that less than a foot separated them. Apogee was 193 miles; perigee 100.

Gemini VI–A splashed down in the western Atlantic 25 hours, 51 minutes, and 24 seconds after its launch, impacting within seven miles of the planned landing point. Schirra and Stafford



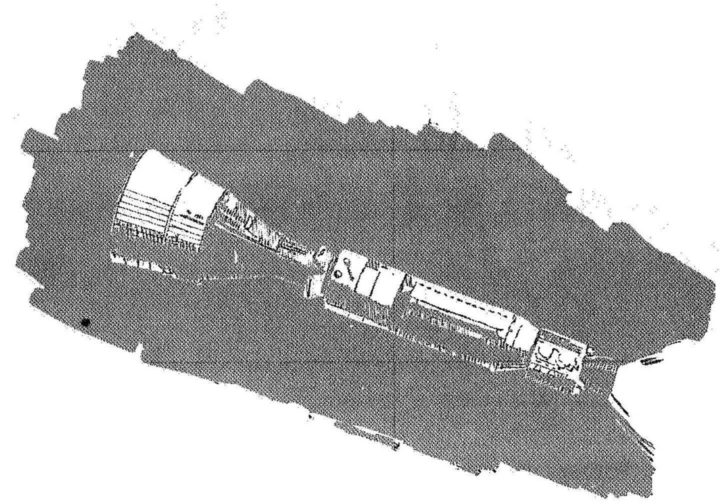
remained with the spacecraft until it was picked up by the U.S.S. *Wasp*, the prime recovery ship.

Gemini VII: Astronauts Frank Borman and James A. Lovell, Jr., were command pilot and pilot, respectively, of Gemini VII, which established a record for the longest manned space flight. This 14-day mission was primarily designed to carry out long duration flight and to evaluate the effects on the crew. In addition, the astronauts made their craft a target for Gemini VI–A, conducted station keeping with that spacecraft, performed 20 experiments, wore lightweight pressure suits, and evaluated the spacecraft reentry guidance capability.

Gemini VII was launched at approximately 2:30 p.m., December 4, 1965, and touched down in the western Atlantic recovery zone, just 6.4 miles from the planned landing point at 9:05 a.m., on December 18, after a flight lasting 330 hours and 35 minutes. Borman and Lovell went aboard the *Wasp,* recovering its second Gemini crew within 3 days, in a helicopter at 9:37 a.m., and their spacecraft was taken aboard at 10:08 a.m.

During the flight, Lovell removed his pressure suit on the second day, and from that time until the end of the flight either one or both of the crew were out of their suits most of the time. The total elapsed time of the flight was about twice that anticipated necessary for a lunar landing mission.

Gemini VIII: Gemini VIII was launched March 16, 1966, following the 10:00 a.m.-launch of the Gemini VIII Agena target by 1 hour and 41 minutes. Neil A. Armstrong was command pilot and David R. Scott, pilot, of the flight which established several records before its early termination. Six hours after lift-off the spacecraft made the first rendezvous with an unmanned target vehicle and shortly afterward joined the target vehicle to achieve



the first docking of two vehicles in space. This historic event occurred approximately six hours and 33 minutes after the Gemini VIII lift-off.

Approximately 27 minutes after docking the spacecraft-target vehicle combination began to yaw and roll much faster than expected. Attempts to bring the vehicles under control by giving various commands to the Agena were not successful until the spacecraft was separated from the target vehicle, and the astronauts deactivated the orbital attitude maneuver system and activated the reentry control system. The mission was ordered to be terminated during the seventh revolution, requiring a landing in a secondary recovery area. Gemini VIII touched down in the western Pacific east of Okinawa, after an elapsed flight time of about 10 hours and 41 minutes. Touchdown occurred about 1.1 miles south of the planned landing area at 10:22 p.m. The crew was picked up by the U.S.S. *Mason,* a destroyer, at 1:28 a.m, March 17, and the spacecraft was picked up about an hour later.

Gemini IX: Gemini IX was scheduled as another rendezvous mission with an Agena target. However, the Atlas booster for the target vehicle failed shortly after lift-off on May 17, 1966, causing the mission to be terminated and rescheduled for June 1, with an Augmented Target Docking Adapter (ATDA) substituted for the Agena as the Target vehicle.

Gemini IX–A: On June 1, the target vehicle (ATDA) for Gemini IX–A was launched at 10:00 a.m. and placed into an

orbit with an apogee of 185 miles and a perigee of 183 miles. The flight crew—astronaut Thomas P. Stafford, command pilot, and astronaut Eugene A. Cernan, pilot—was in the spacecraft and participated in the countdown. However, when time came for the spacecraft launch, the guidance information for the spacecraft computer could not be transferred from the ground equipment to the spacecraft, and the launch was rescheduled for June 3.

On that day, the countdown went smoothly, and Gemini IX–A was launched at 8:39 a.m. Major objectives of the mission were to rendezvous with the target during the third revolution, to re-rendezvous during the fourth revolution, to rendezvous from above during the 12th revolution, to conduct extravehicular activities, to demonstrate a controlled reentry, and to practice docking. All objectives except the last were achieved.

Gemini IX–A made rendezvous with the ATDA 4 hours and 15 minutes after lift-off and performed station keeping activities for 46 minutes. Stafford and Cernan rerendezvoused with the target after 6 hours and 36 minutes of the mission had elapsed, carrying on station keeping for 39 minutes. The third rendezvous (from above), the most difficult to achieve because of the terrain in the background, was accomplished after 21 hours and 42 minutes of flight, and the station keeping period lasted 1 hour and 17 minutes. The hatch was open for extravehicular activity 49 hours and 23 minutes after lift-off and closed again after 51 hours and 30 minutes—a total extravehicular time of 2 hours and 7 minutes. Apogee was 194 miles, perigee 98 miles.

The Gemini IX–A spacecraft touched down about 0.4 miles from the planned landing point in the western Atlantic at 9:00 a.m., June 6, 72 hours and 21 minutes after lift-off. Crew and spacecraft were recovered by the U.S.S. *Wasp* at 9:53 a.m.

Gemini X: Astronauts John W. Young and Michael Collins were command pilot and pilot, respectively, for the Gemini X mission which was conducted July 18–21, 1966. Its major objectives were to rendezvous and dock with an Agena target vehicle, to use large propulsion systems in space, to conduct extravehicular activities, and to practice docking. Only the final objective was not achieved.

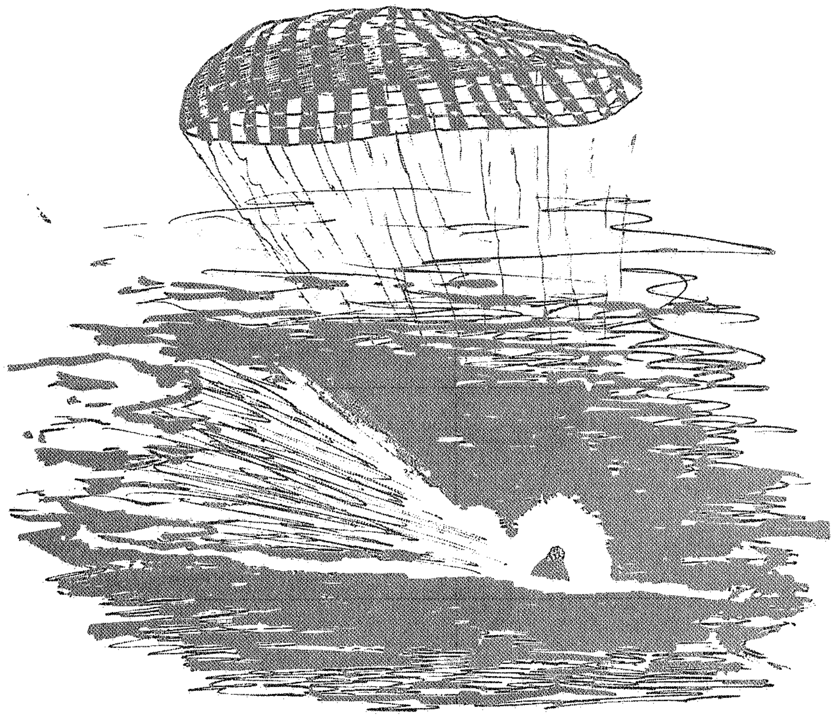
On July 18, the Agena target was launched at 3:39 p.m., followed by the Gemini launch at 5:20 p.m. The timing was in exact accord with the flight plan and allowed Gemini X to rendezvous with its target 5 hours and 21 minutes later. The docking of the two craft took place 31 minutes later, and the two vehicles operated in the docked configuration for 38 hours and 47 minutes, using the Agena primary and secondary propulsion systems an equal number of times to perform 6 major maneuvers.

The first major maneuver placed the combined craft in an elliptical orbit with an apogee of 476 miles and a perigee of 182 miles. During the docked period, the crew participated in its first major extravehicular activity. Starting after 23 hours and 24 minutes of the flight had elapsed, the hatch was opened for 49 minutes, while Collins performed tasks assigned to that phase of the mission. The standing EVA was terminated when both crew members experienced eye irritation. The second EVA period, which started 48 hours and 41 minutes after lift-off, was an umbilical EVA activity with Collins emerging from the spacecraft and remaining out for 39 minutes. During this time he retrieved an experiment package which had been attached to the Agena VIII since March.

The Gemini X spacecraft touched down in the Atlantic at 4:07 p.m., July 21, about 3½ miles from the planned impact point. The crew was picked up by helicopter and placed aboard the U.S.S. *Guadalcanal* 27 minutes after landing. Another 27 minutes passed before the *Guadalcanal* picked up their spacecraft.

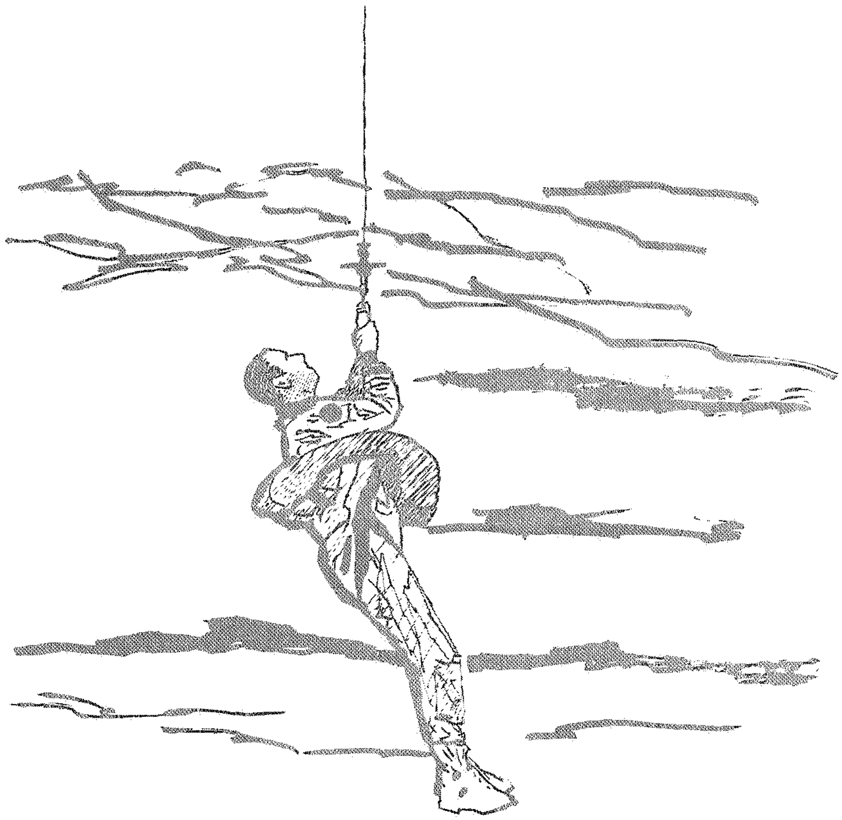
Gemini XI: Astronauts Charles Conrad, Jr. (command pilot) and Richard F. Gordon, Jr. (pilot) served as crew of the Gemini XI mission conducted September 12–15, 1966. The Atlas-Agena target was launched at 8:05 a.m., followed by the Gemini lift-off at 9:42 a.m. Gemini XI had an ambitious flight plan and most of the mission objectives were achieved. One of the most important accomplishments of the flight was the successful rendezvous and docking with the Agena target vehicle during the spacecraft's first revolution. Another important achievement was attaining the highest altitude ever reached in a manned flight. During the second day of the mission and while docked with the target, the crew used the Agena primary propulsion system to boost the combined vehicles into an elliptical orbit with an apogee of 853 miles and a perigee of 178 miles. During his umbilical EVA, astronaut Gordon fastened a tether from the target vehicle to the spacecraft docking bar. However, he had to expend a great amount of energy, and the activity was terminated and the hatch closed after 33 minutes.

On the third day of the flight, the Gemini XI crew achieved another first by undocking from the Agena and performing a successful tethered operation. The two spacecraft made about two revolutions around the earth while tethered. Other notable achievements of the flight included the first rendezvous accomplished by using on-board computations, and the first docking practice in space, when both pilots performed the docking maneuvers twice. The final phase of the flight was another important first—the automatic, computer-controlled reentry. Retrofire oc-



curred over the Canton Island tracking station at an elapsed time of 70 hours, 41 minutes, and 36 seconds, and the impact took place (2.7 miles from the target point) about 35 minutes later. Conrad and Gordon were taken to the U.S.S. *Guam,* the prime recovery ship, by helicopter 24 minutes after they landed, and the spacecraft was retrieved 35 minutes later.

Gemini XII: The final flight of the Gemini Program began November 11, 1966, and ended four days later. On launch day, the Atlas-Agena lift-off occurred at 2:08 p.m. and the Gemini lift-off at 3:46 p.m. Gemini XII was designed to gain additional information about extra-vehicular activity requirements, to rendezvous and dock with a target, and to perform a number of experiments. It was an unqualified success, for, in addition to achieving these and other objectives, its crew—command pilot James A. Lovell, Jr., and pilot Edwin E. Aldrin, Jr.—set several individual space records. Lovell has logged more hours in space flight than any other man—425 hours, 10 minutes and 2 seconds. Aldrin logged more extravehicular time than any other man—a 2-hour, 27-minute-standup EVA; a 2-hour, 8-minute-umbilical EVA; and another 51-minute-standup EVA—a total of 5 hours and 26 minutes. Use of handrails, foot restraints, and waist tethers dur-



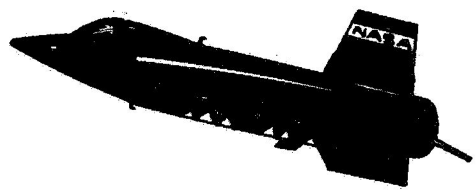
ing the umbilical EVA proved to be most effective, and Aldrin completed all 19 assigned tasks.

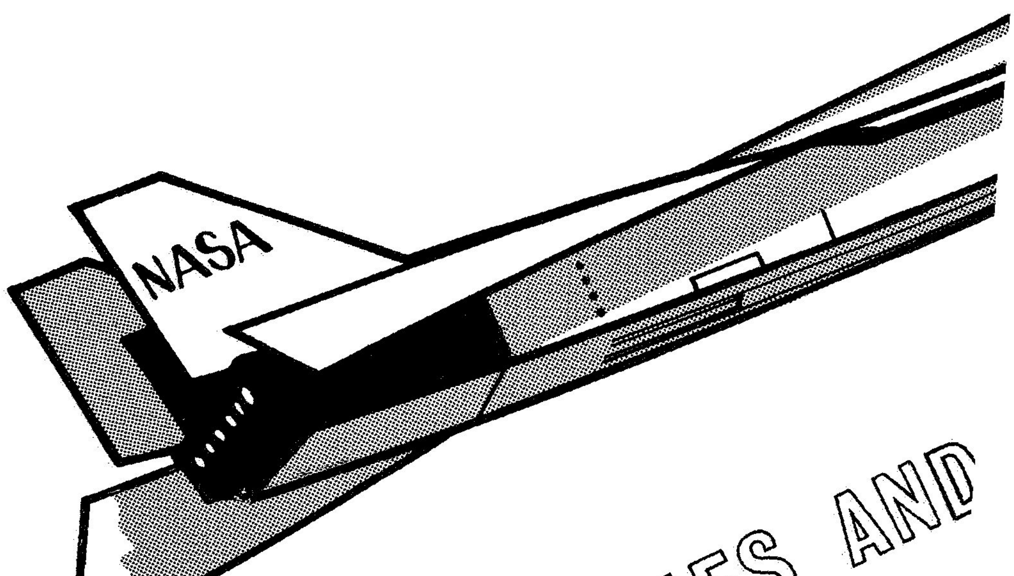
Retrofire was initiated over Canton Island at 93 hours, 59 minutes, and 58 seconds elapsed time, and landing occurred 34 minutes and 33 seconds later at 2:21:04 p.m., within 2.6 miles of the planned landing point. The floatation collar was attached eight minutes after impact, and Lovell and Aldrin were picked up by helicopter and taken to the deck of the U.S.S. *Wasp* 30 minutes after they had landed. The last Gemini spacecraft to fly in the program was brought aboard the *Wasp* 1 hour and 7 minutes after splashdown.

APOLLO

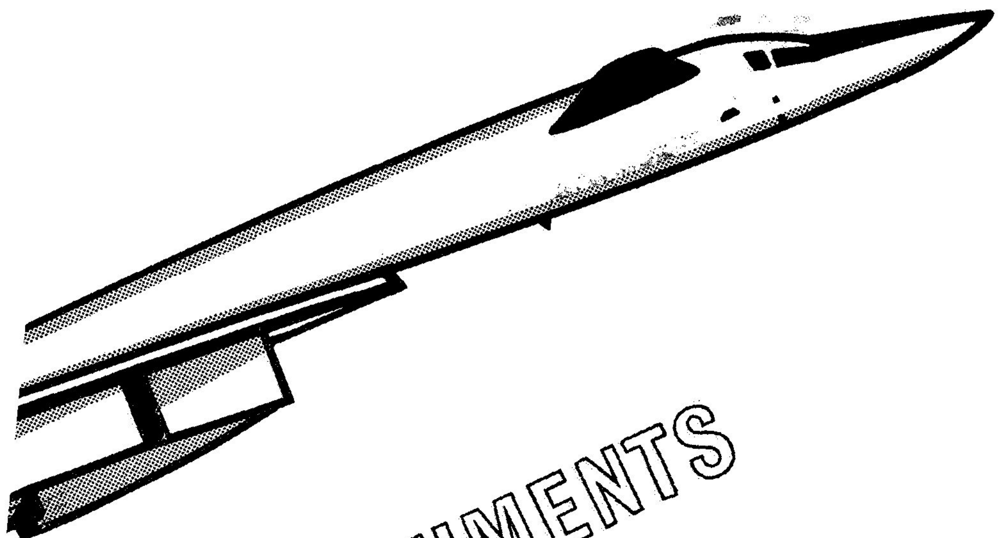
The experience and confidence gained from sixteen successful manned Mercury and Gemini missions enabled the space program to move in an orderly fashion toward the third phase of manned

space flight—Apollo. The techniques of spacecraft control, of rendezvous and docking, and of extravehicular activity—all prerequisite to Apollo missions—were effectively developed and tested. The soundness of the tracking and data acquisition systems was clearly demonstrated, and the necessary life support and physiological monitoring systems proved to be both reliable and efficient. With these successes to build on, the Nation's manned space program was ready to proceed with the Apollo program.

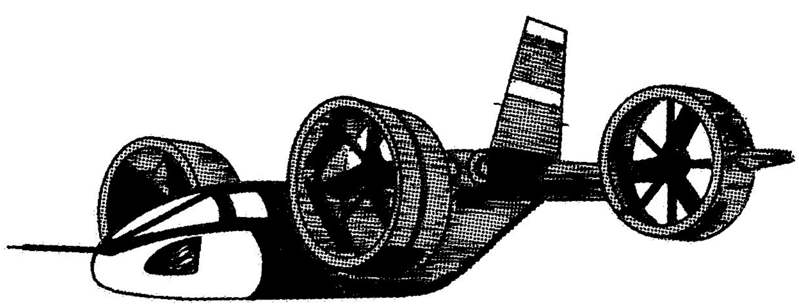


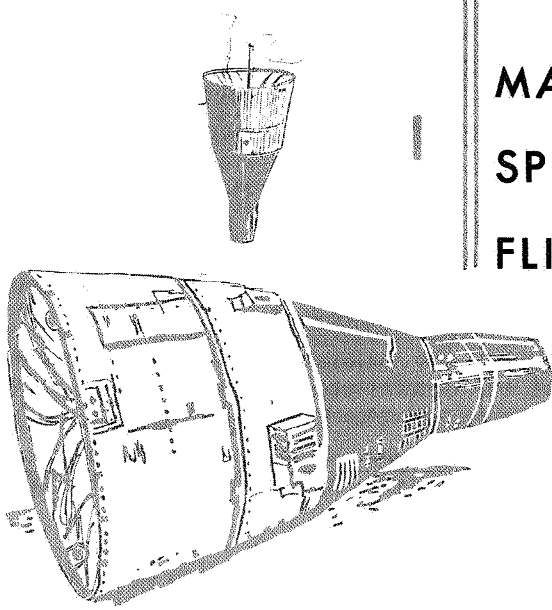


ACTIVITIES AND



ACCOMPLISHMENTS





MANNED SPACE FLIGHT

NASA's manned space flight program achieved some of its most significant results during the six-month period covered by this report. The tenth, eleventh, and twelfth Gemini missions were successfully completed, two unmanned Apollo/Uprated Saturn I test missions were conducted, and the Apollo program progressed to preparation for the first manned Apollo mission.

With the final Gemini flight, the manned space flight program had logged almost 2,000 hours in space. The Gemini program had accomplished all program objectives. Specifically, it had demonstrated that man can live and work effectively in weightless space flight for periods up to 14 days. It had accomplished rendezvous of a manned spacecraft with an unmanned target vehicle and docking the two together. It had conducted maneuvers with such a docked vehicle, and used the propulsion stage to fly men higher and faster than they had ever flown before. It had demonstrated, after more than 12 hours of experience, that man can perform useful activity outside a spacecraft in a protective suit. It had proved possible the control of missions and operation of manned spacecraft traveling in orbit at speeds of almost 18,000 miles an hour. It had carried out precision landings of manned spacecraft, within sight of the recovery ships. And it had accomplished significant scientific and technological experiments in space.

More broadly, NASA continued to make progress toward accomplishing such general objectives of manned space flight as

identifying and proving man's capabilities in the space environment, advancing toward extended exploration of space (including a manned lunar landing), and establishing a mature and effective national capability for carrying out long range man-in-space programs.

The industrial work force associated with the manned space effort totaled approximately 250,000 people at the end of 1966. Some 14,000 people in government were also involved in the program. Broad support continued to be forthcoming from both the university segment of our society and the military.

While the basic structure of the manned space flight organization remained unchanged, the Gemini program organization was essentially phased out. The people who had carried the program through to successful completion were moved to other key assignments, chiefly in the Apollo, the Apollo Applications, and the Advanced Manned Missions programs.

GEMINI PROGRAM

The last three manned flights of the Gemini Program were completed between July and December of 1966. Primary objectives of the three flights—Gemini X, XI, and XII—were rendezvous and docking, and extravehicular activity. During the Gemini X mission, in July, the Agena target vehicle's primary propulsion system was first used to boost the docked vehicle combination to an altitude record of 476 miles. Also on this flight, re-rendezvous with a passive target (the Gemini VIII Agena target vehicle) was accomplished.

During the Gemini XI mission in September, a first orbit rendezvous and docking was achieved. The altitude record established by Gemini X was broken when the Gemini XI/Agena XI target vehicle reached an altitude of 853 miles.

On the Gemini XII flight, in November, the astronauts achieved the first completely successful extravehicular activity since Gemini IV in 1965, and obtained a photograph of the solar eclipse. On all three of these flights numerous scientific and technological experiments were completed.

Gemini X

Gemini X was the eighth manned mission and the fourth rendezvous mission of the Gemini Program. The Gemini Agena Target Vehicle (GATV) was launched from Complex 14, Cape Kennedy, Fla., at about 3:40 p.m. (all times are Eastern Standard), on July 18. The Gemini Space Vehicle was launched from Complex 19, approximately one hour and 40 minutes later, with

Astronaut John W. Young as the Command Pilot and Astronaut Michael Collins as the Pilot. The flight was concluded on July 21, when the spacecraft landed within sight of the prime recovery ship after a mission lasting about 71 hours. The astronauts were picked up by helicopter and put on the deck of the prime recovery ship approximately 28 minutes after landing.

The primary objective, to rendezvous and dock, was completed. Besides achieving this objective during the fourth revolution, the astronauts used large propulsion systems in space (Gemini Agena Target Vehicle primary and secondary propulsion systems), conducted extravehicular operations, and carried out systems evaluations. Another secondary objective, to conduct experiments, was only partially achieved. Some experiments could not be completed because of time limitations and a constraint on the use of spacecraft propellants. For the same reasons, the astronauts did not attempt to conduct docking practice.

The launch of the Gemini Atlas-Agena Target Vehicle was satisfactory. The countdown was completed with no holds, and the vehicle was placed in a near-circular orbit having an apogee of 185 miles and a perigee of 179 miles.

The lift-off of the Gemini space vehicle occurred approximately 1 hour and 40 minutes after lift-off of the target vehicle. The space vehicle's performance during the countdown and launch was satisfactory in all respects. The apogee of the first orbit was 166 miles, and the perigee was 99 miles. These altitudes were only 0.1 of a mile low at apogee and 0.4 of a mile low at perigee, when compared with the planned altitudes. The slant range to the target vehicle was very close to 1,143 miles.

Twenty minutes after launch at the start of the first darkness period, the crew began a series of measurements and computations required for the maneuvers leading to rendezvous, using the onboard computer to calculate the solutions. The crew completed the rendezvous during the fourth revolution, as planned, at 5 hours 23 minutes ground elapsed time (g.e.t.), docked with the target vehicle about 30 minutes later, and remained docked for approximately 39 hours (Fig. 1–1).

During this time, the spacecraft Orbital Attitude and Maneuver System thrusters were used for a bending mode test to determine the dynamics of the docked vehicles. Standup extravehicular activities (EVA) were also conducted starting at 23:24:00 g.e.t. (sunset), after the spacecraft was depressurized and the hatch was opened without difficulty. The extravehicular pilot performed the ultraviolet astronomical camera experiment during the night pass and began the color patch photography experiment after sunrise. However, the astronauts reported that eye irritation

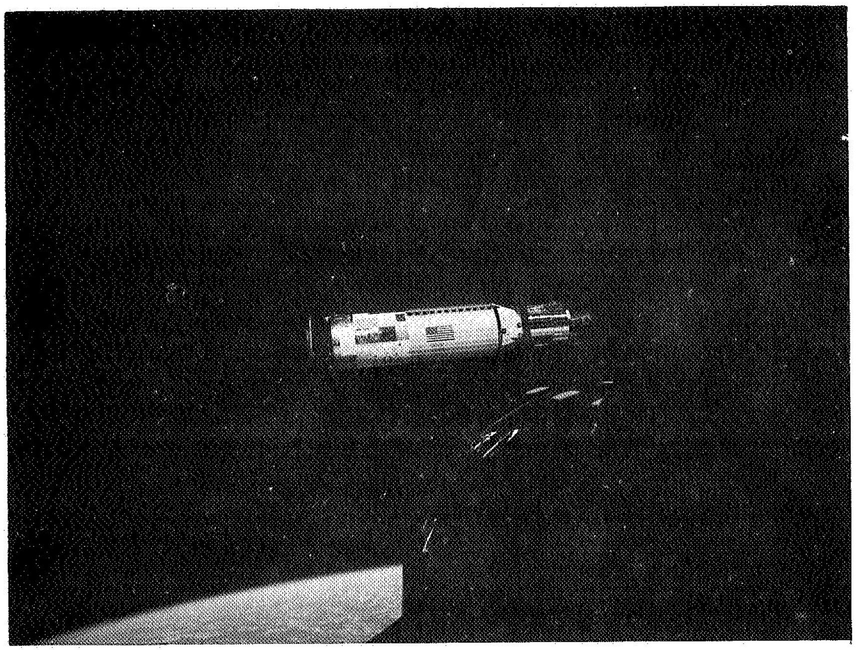


Figure 1–1. The Gemini Agena Target Vehicle seen from Gemini X.

hampered vision so much that they could not see to make the camera adjustment to complete the latter experiment. Consequently, they terminated the EVA six minutes early, at 24:13:00 g.e.t. The color plate for the experiment was discarded because the pilot could not see to disconnect it from the rod before throwing the rod away.

The sudden onset of eye watering and irritation reported by both crewmen at approximately 24 hours g.e.t. was sufficiently severe to cause termination of the standup EVA. The precise cause of this irritation remains a mystery. Post-flight chemical analyses of particles removed from the Environmental Control System showed that all samples were very similar to those observed after previous flights and were, therefore, to be expected. A second possibility considered was that the irritation may have been caused by the operation of two suit-fans during the EVA. The low suit pressure (3.7 psia) and both fans operating produces the highest level of velocity across the face. Hence, it was suspected that this combination may have caused the eye irritation, and, on subsequent flights, EVA was conducted with only one fan operating. Under the latter conditions, the problem did not recur.

The target vehicle propulsion system was used to accomplish six maneuvers of the docked vehicles in preparation for the rendezvous

with the passive Gemini VIII Agena Target Vehicle. The primary propulsion system was used for three of the maneuvers and the secondary propulsion system for the other three. At approximately 44:40 g.e.t., the spacecraft was separated from the Gemini X target vehicle, and the remaining maneuvers for the second rendezvous were made by using the spacecraft thrusters.

The second rendezvous was completed at 48 hours g.e.t. The Gemini VIII target vehicle was in a stable attitude, and the command pilot was able to maneuver to within a short distance of it. The second extravehicular activity, during which a 50-foot umbilical and the extravehicular life support system chestpack were used, began at 48:42 g.e.t. (Fig. 1–2). After making the necessary preparations, the pilot moved to the Gemini VIII Target Vehicle and retrieved the micrometeorite collection package attached to it. During the extravehicular activity, the command pilot maneuvered the spacecraft so that he could see both the pilot and the target vehicle. This procedure consumed an excessive amount of propellant; therefore, the EVA was terminated after about 38 minutes to conserve propellant for the remaining required maneuvers. The hatch was opened again about an hour later to jettison extraneous equipment in preparation for reentry.

After the third sleep period, the crew performed several more experiments and made final preparations for retrofire which occurred at approximately 70:10 g.e.t. The landing occurred at 70 hours 46 minutes g.e.t. in the primary landing area within sight of the prime recovery ship. The crew elected to be flown by helicopter to the U.S.S. *Guadalcanal* and were aboard 28 minutes after landing.

After the spacecraft landed, ground controllers directed the Gemini X target vehicle to perform three maneuvers which placed it in a 217-mile circular orbit for possible use as a passive target on future missions.

Of the fourteen experiments planned for the Gemini X mission, all but two were either completed or partially completed. The landmark contrasts measurements experiment was not performed, and the micrometeorite collection experiment was lost outside the spacecraft. The table (p. 35) shows both planned and actual experiment activity on Gemini X.

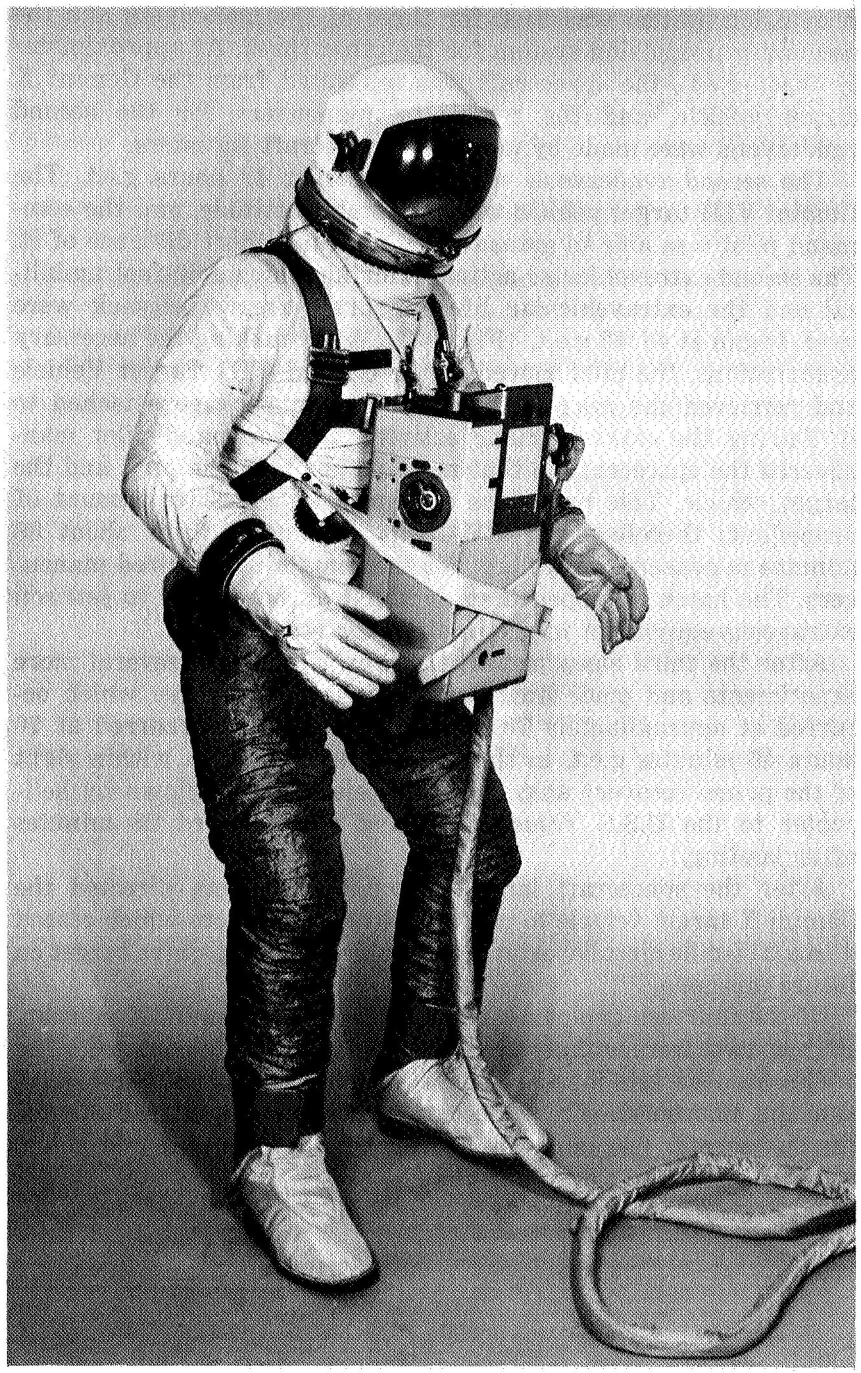


Figure 1–2. Extravehicular life support system chestpack.

Experiment Title	Planned Activity	Actual Activity
Tri-Axis Magnetometer	3 days	3 days.
Beta Spectrometer	do	Do.
Bremsstrahlung Spectrometer	do	Do.
Color Patch Photography	1 day pass sequence	1 day pass sequence.
Landmark Contrast Measurements.	4 day pass ground observations.	None.
Star Occultation Navigation	4 night passes	1.3 night passes.
Ion-Sensing Attitude Control	10 sequences	6 sequences.
Zodiacal Light Photography	1 night pass sequence	0.2 night pass sequences.
Synoptic Terrain Photography	3 day pass sequences	1.5 day pass sequence.
Synoptic Weather Photography	5 day pass sequences	4 day pass sequences.
Agena Micrometeorite Collection	Recover one unit, activate another.	Recover one unit.
Micrometeorite Collection	8 hours exposure	Experiment lost.
UV Astronomical Camera	1 night pass sequence	0.5 night pass sequences.
Ion Wake Measurements	3 undocking sequences	1 undocking sequence.

Gemini XI

The ninth manned Gemini mission (Gemini XI) was the fifth rendezvous and third docking mission of the program.

The Gemini XI GATV was launched from complex 14 at 8:05 a.m., on September 12, after the countdown had been delayed by a ten-minute hold called because of a spacecraft hatch seal problem. (Fig. 1–3.) The Gemini XI spacecraft with Astronauts Charles Conrad as Command Pilot and Richard F. Gordon as Pilot was launched 1 hour and 37 minutes later from complex 19. The spacecraft made rendezvous by using 5 maneuvers and docked with the Gemini XI GATV 1 hour and 34 minutes after lift-off during its first revolution. During the succeeding 4 hours and 25 minutes, the crew performed various sequences of the ion-wake experiment, in addition to 3 undockings and dockings (2 by the pilot).

At 24 hours 2 minutes g.e.t., the spacecraft hatch was opened for the umbilical EVA. After setting up a camera and retrieving an experiment package from the spacecraft exterior, the EVA pilot moved to the spacecraft nose and attached a one-hundred foot Dacron tether from the GATV to the docking bar. (Fig. 1–4.) Since this activity was exceedingly tiring for the pilot, the EVA was terminated and the hatch closed after 33 minutes.

At 40 hours and 30 minutes g.e.t., the GATV primary propulsion system was ignited for a second time, and the apogee of the docked vehicles was raised to 853 miles. This orbit was maintained for two full revolutions, during which numerous photography experiments were performed. A retrograde maneuver, again using the Agena primary propulsion system, was initiated at 43 hours 53 minutes g.e.t., and the resulting apogee was 187 miles.

A 2-hour and 8-minute standup EVA period was initiated at 46 hours 7 minutes g.e.t., and during its two night passes, the pilot

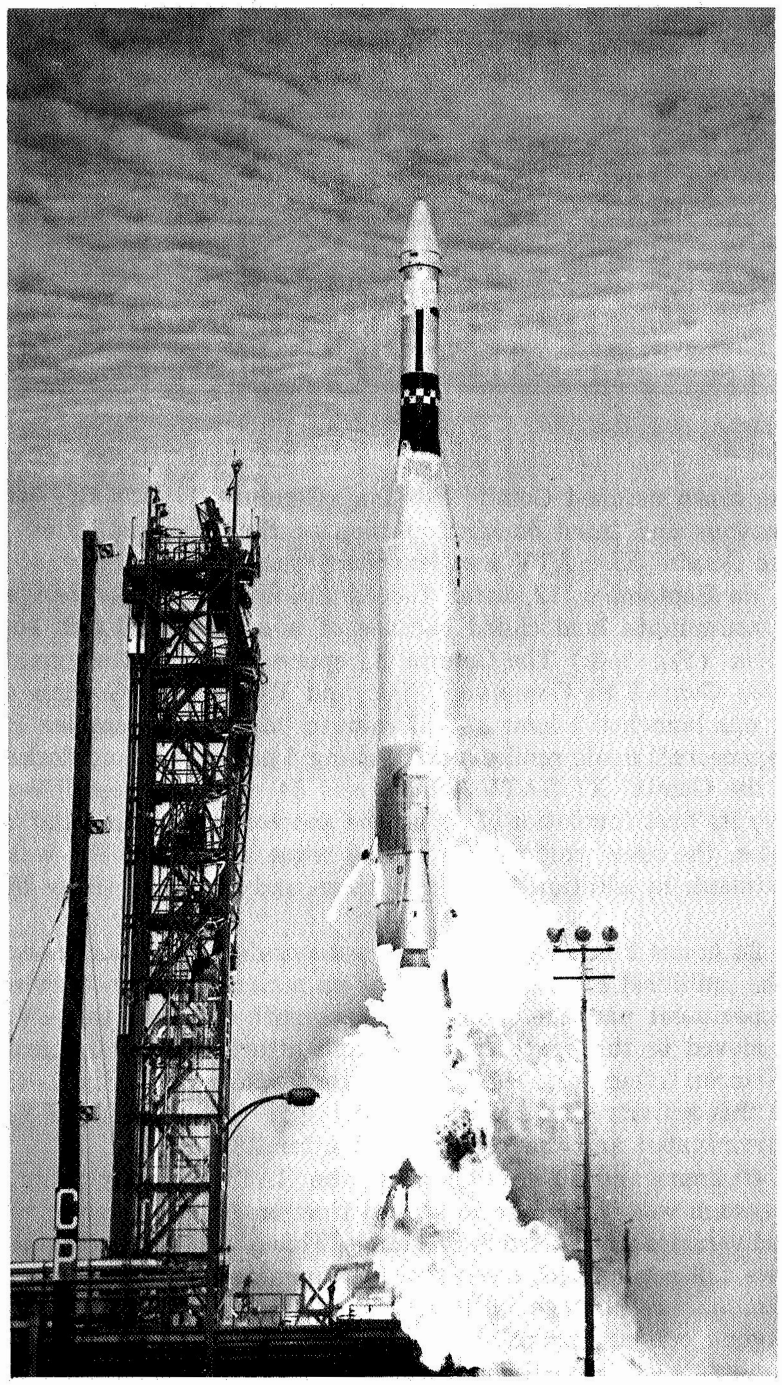


Figure 1-3. Launch of Gemini XI GATV.

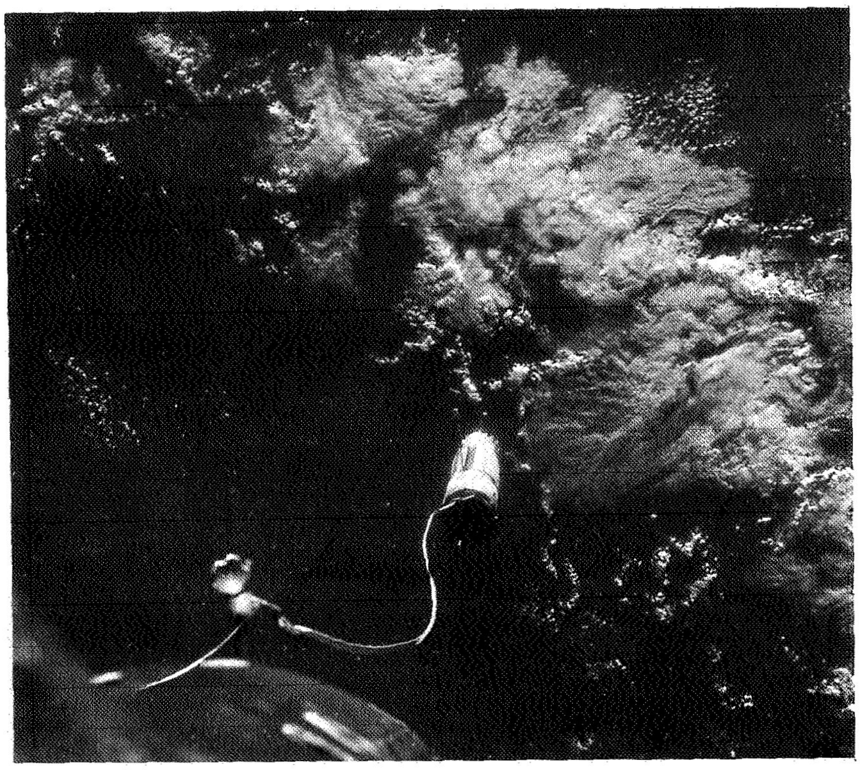


Figure 1–4. Dacron tether between Gemini XI and GATV.

took a number of experiment photographs. At 49 hours and 55 minutes g.e.t., the spacecraft and the GATV undocked, moving apart to the extended length of the tether, and approximately 20 minutes later the crew began rotating the tethered vehicles, achieving an initial rate of 38° per minute. After another 20 minutes the system became stable. About two hours later, the rotational rate was increased to 55° per minute, the spacecraft control system was used to reduce oscillatory motion, and the system stabilized at the higher rotational rate. This experiment suggested that an economical method of long-term, unattended stationkeeping had been devised. At approximately 53 hours g.e.t., the tether was separated by jettisoning the docking bar.

Next, separation and standoff maneuvers were performed to place the spacecraft in a coincident orbit with the GATV in preparation for a rerendezvous to be attempted following the third sleep period. At 65 hours 27 minutes g.e.t., a series of maneuvers was initiated to complete the coincident orbit rendezvous, and the spacecraft was again stationkeeping with the target vehicle at 66 hours 40 minutes g.e.t.

Retrofire occurred at about 70 hours 41 minutes g.e.t., and the

spacecraft made an automatic, computer-controlled reentry. It landed approximately 2½ miles from the recovery ship, the U.S.S. *Guam*. The astronauts chose to leave the spacecraft by helicopter and were aboard the recovery ship about 24 minutes after landing. The spacecraft was later hoisted aboard the carrier.

Twelve scientific or technological experiments were originally planned for the Gemini XI mission. The 3-day delay resulted in cancellation of the libration regions photography experiment because the earth-moon libration regions became obscured by the Milky Way star background. Ten of the remaining eleven were carried out, either partially or completely. The following table shows the experiment title and indicates quantitative success of each:

Experiment Title	Planned Activity	Actual Activity
Mass Determination	1 Docked Thrust Sequence	1 Docked Thrust Sequence.
Night Image Intensification	2 Night Passes	2 Night Passes.
Power Tool Evaluation	1 Umbilical EVA Sequence	None.
Radiation and Zero G on		
(1) Blood.	(1) 1 Hour Exposure.	(1) 1 Hour Exposure.
(2) Neurospora.	(2) 38 Hour Exposure	(2) 38 Hour Exposure.
Synoptic Terrain Photography	2 Day Pass Sequences	2 Day Pass Sequences.
Synoptic Weather Photography	2 Day Pass Sequences	2 Day Pass Sequences.
Nuclear Emulsion	22 Hours Activation	22 Hours Activation.
Airglow Horizon Photography	3 Night Passes	3 Night Passes.
UV Astronomical Camera	2 Night Passes (Standup EVA).	2 Night Passes (Standup EVA)
Ion Wake Measurement	4 SC Wake Measurement Sequences.	4 SC Wake Measurement Sequences.
Dim Sky Photographs/Orthicon	1 Night Pass	1 Night Pass.

Analyses of available photographic and telemetry data indicate that the fundamental objectives were obtained for 9 of the 11 experiments. The power tool evaluation experiment was not attempted because of premature termination of the umbilical extravehicular activities. The dim sky photographs/orthicon experiment was successfully performed; however, only one of the several scheduled activities was photographically recorded.

Gemini XII

Gemini XII was the tenth manned mission and the sixth rendezvous mission of the Gemini Program. The GATV was launched from complex 14, at 2:07:59 p.m., on November 11. The Gemini Space Vehicle was launched from complex 19, approximately 1 hour and 40 minutes later, with Astronaut James A. Lovell as the Command Pilot and Astronaut Edwin E. Aldrin as the Pilot. The flight was successfully concluded on November 15, when the spacecraft landed within 2.6 miles of the prime recovery ship, the U.S.S. *Wasp*, at 94:34:31, spacecraft ground elapsed time (g.e.t.) from

lift-off of the Gemini Space vehicle. (All elapsed time figures in the remainder of this section are also g.e.t.)

The two primary objectives of the mission—to rendezvous and dock, and to evaluate extravehicular activities—were achieved. The eight secondary objectives were to conduct a tethered-vehicle evaluation; perform experiments; rendezvous and dock during the third spacecraft revolution; execute docked maneuvers for a high-apogee excursion; practice docking; make system tests; park the GATV; and demonstrate automatic reentry. All the secondary objectives were achieved except two. The high-apogee excursion was not attempted because of an anomaly noted during the primary propulsion system firing of the GATV at the time of insertion. And the attempt to park the GATV after the spacecraft landed was unsuccessful because a turbine overspeed caused the primary propulsion system to shut down before main engine ignition.

The GATV achieved a nearly circular orbit with an apogee of 187 miles and a perigee of 182 miles. Lift-off of the Gemini Space Vehicle occurred approximately 1 hour 38 minutes after lift-off of the GATV. (Fig. 1–5). The powered flight of the Space Vehicle was satisfactory in all respects, and the spacecraft was separated from the launch vehicle approximately 23 seconds after second stage engine cutoff.

The crew performed nine maneuvers to effect a third-orbit rendezvous with the GATV. Before the terminal phase maneuver, the onboard radar malfunctioned; however, the crew used onboard backup procedures, including optical tracking techniques and prepared backup charts, to make the necessary maneuver calculations. The rendezvous was completed at 3 hours 46 minutes and the Command Pilot docked the spacecraft with the GATV at 4 hours 14 minutes.

At 5 hours 44 minutes, the flight controller on the Coastal Sentry Quebec tracking ship reported that the fuel cell oxygen-to-water differential pressure warning lights were on. After approximately 7 hours, the crew used water to prepare a meal and the lights went out. The lights came on again shortly thereafter and remained on until the circuit breaker was turned off.

Because of the decision not to operate the GATV primary propulsion system for the high-apogee excursion, photographing the solar eclipse was scheduled into the flight plan. At 7 hours 5 minutes, the GATV secondary propulsion system was used to perform a docked maneuver of 43 ft/sec to phase the orbit for the eclipse photography. After the first sleep period, at 15 hours 16 minutes, the secondary propulsion system was used for a second phasing maneuver requiring a velocity change of 15 ft/sec.

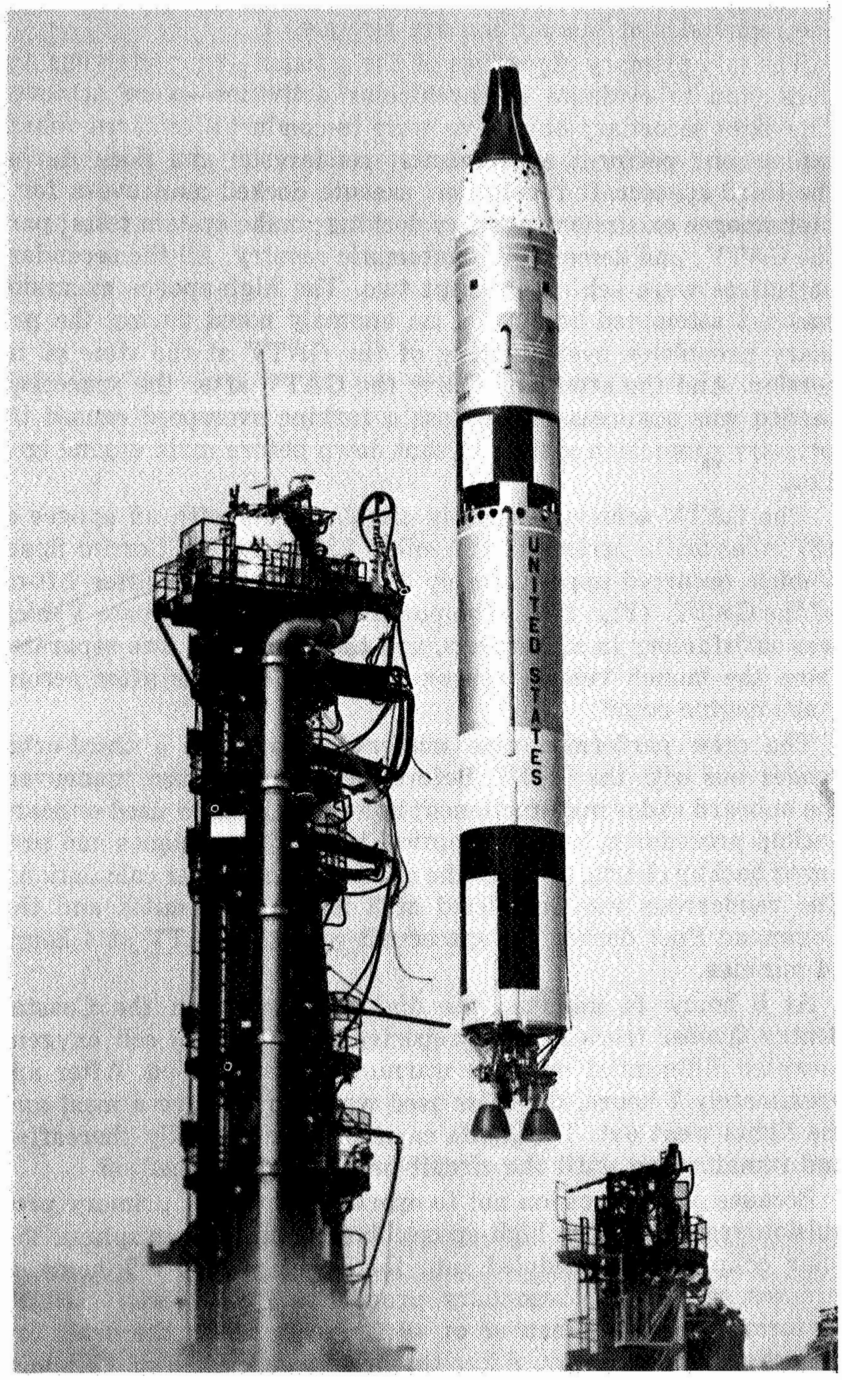


Figure 1–5. Gemini XII launch.

The crew photographed the solar eclipse but could not photograph the shadow of the moon on the earth.

The first of two standup EVA periods began at 19 hours 29 minutes. During the 2 hours 26 minutes the pilot was outside the spacecraft, he installed the telescoping handrail between the spacecraft and the GATV (fig. 1–6), performed photographic experiments, and retrieved the micrometeorite collection device which was on the adapter, just behind the open hatch. The remainder of the second day was spent performing sequences of various experiments, and the second sleep period was started at 29 hours 30 minutes.

The crew was awakened at 36 hours 50 minutes to purge the fuel cells because of further troubles. The purge did not correct the problem, and at 37 hours 40 minutes, stack B of fuel cell section 2 failed and was removed from the line. During the next two hours, the crew performed several experiments, and at 39 hours 30 minutes they reported that little or no thrust was available from a pitch-down thruster and a yaw-right thruster.

Preparations for umbilical EVA were begun at 39 hours 40 minutes, and the hatch was opened at 42 hours 49 minutes. The pilot moved to the Target Docking Adapter and attached a 100-foot tether from the GATV to the spacecraft docking bar. He then moved to the area of the micrometeorite collection package

Figure 1–6. Astronaut Aldrin installing telescoping handrail.

mounted on the target vehicle, and, with the aid of two waist tethers and a special attachment system, opened the package to expose the collection surfaces to the space environment. Next, he moved to the spacecraft adapter, where he evaluated several restraint systems and performed various preassigned work tasks. After completing these tasks, he returned to the target vehicle to evaluate additional restraint systems and aids, including two portable handholds, and to perform another series of work tasks. All tasks during the umbilical EVA were completed, and the pilot returned to the cockpit and closed the hatch at 44 hours 55 minutes.

At 47 hours 23 minutes, the crew undocked the spacecraft from the GATV and began the tether evaluation. The tether tended to remain slack and to tauten only occasionally; however, according to the crew, the two vehicles did slowly attain gravity-gradient stabilization. The tether evaluation continued until 51 hours 51 minutes, at which time the crew jettisoned the docking bar and released the tether. About 23 minutes later, the crew performed a maneuver, using the spacecraft propulsion system, to separate the spacecraft from the target vehicle.

After the third sleep period, the crew performed a phase adjust maneuver at 61 hours 48 minutes, and began several experiments. At 62 hours 42 minutes, and again at 64 hours 17 minutes, a sodium-cloud rocket was launched from the French launch site in Algeria. Although the astronauts could not see either cloud, they took photographs of the planned areas.

Because of experiment activities, preparation for the second standup EVA became somewhat hurried and the crew requested a one-revolution delay. At 66 hours 5 minutes, the hatch was opened for the EVA and several photographs were taken. The crew performed all planned experiment sequences, and the hatch was closed at 67 hours 1 minute.

The crew reported further problems with the spacecraft attitude control thrusters at 68 hours; one yaw-left thruster was apparently inoperative, and the second yaw-left thruster was severely degraded. Before the fourth sleep period, the crew performed various sequences of several experiments. Fuel cell stack 1C failed during the sleep period, and the astronauts were awakened early to turn off the switch, stopping the flow of reactants to this stack.

After the sleep period, the crew again performed experiments. A test of the propulsion system, conducted at 88 hours 57 minutes, indicated that two thrusters were delivering no measurable thrust and two others were degraded. At 89 hours the two remaining stacks—2A and 2C—in fuel cell section 2 were carrying less than

one-half their normal share of the load. Because of this, two of the four main batteries had to be activated at 91 hours 7 minutes to permit powering up the computer, and the other two batteries were put into service at 92 hours 42 minutes. All load was then removed from section 2 of the fuel cell system.

Retrofire occurred at 93:59:58, and the crew performed all manual functions to prepare the spacecraft for reentry. The landing point was about 2.6 miles from the prime recovery ship, the U.S.S. *Wasp*. (Fig. 1–7.) The astronauts were picked up by helicopter and taken aboard the ship 30 minutes after landing. They were in excellent physical condition.

Fourteen scientific or technological experiments were planned for the Gemini XII mission. An additional nonscheduled activity was performed by the pilot during the second standup EVA. The scientific objective was to take ultraviolet photography of predicted dust clouds within the earth's upper atmosphere. The following table lists the experiments and a gross assessment of performance.

Experiment Title	Planned Activity	Actual Activity
Ion-Sensing Attitude Control	12 Sequences	8 Sequences.
Manual Navigation Sightings	5 Night Passes	5 Night Passes.
Frog Egg Growth	46 hrs Exposure (Sec 1)	42 hrs Exposure.
	85 hrs Exposure (Sec 2)	85 hrs Exposure.
Synoptic Terrain Photography	3 Sequences	3 Sequences.
Synoptic Weather Photography	do	Do.
Agena Micrometeorite Collection	Activate Collector Raise Agena Orbit.	Collector Activated Orbit not Raised.
Airglow Horizon Photography	3 Night Passes	3 Night Passes.
Micrometeorite Collection	8 hrs Exposure	6.5 hrs Exposure.
UV Astronomical Camera	2 Night Passes	2 Night Passes.
Liberation Regions Photographs	do	Camera Malfunction.
Sodium Cloud Photographs	2 Sequences	Do.
Tri-Axis Magnetometer	39 hrs Operation	32 hrs Operation.
Beta Spectrometer	do	10 hrs Operation.
Beta-Bremsstrahlung Spectrometer.	do	32 hrs Operation.

Analyses of available photography and telemetry data indicate that the fundamental objectives were obtained for 11 of the 14 scheduled experiments. The Agena micrometeorite collection experiment was opened by the pilot during umbilical EVA; however, it will not be retrieved because reentry of the target vehicle is not expected to occur before Apollo earth orbital missions. The libration region photography and daytime sodium cloud experiments were successful, but because of camera malfunctions, the exposures obtained were not of usable quality for scientific analysis.

Figure 1–7. Gemini XII astronauts aboard U.S.S. *Wasp*.

THE APOLLO PROGRAM

With the completion of the AS–203 mission on July 5 and AS–202 on August 25, the Apollo program passed key milestones in its mission sequence plan. Attention was next directed toward completing the evaluations preparatory to the AS–204 manned flight scheduled for the first quarter of 1967.

At the end of this report period, LC–34 (LC: Launch Complex) and LC–37 capabilities had been proved, and LC–39 Pad A checkout had been successfully completed using the facility checkout vehicle. Manned flight hardware for the AS–204 flight and unmanned flight hardware for the AS–501 flight was delivered to KSC.

Apollo/Uprated Saturn I Missions

Two Apollo/Uprated Saturn I unmanned missions were completed in this report period. The first mission, AS 201, was successfully conducted on February 26, 1966, and was described in the *Fifteenth Semiannual Report.*

AS 203 Unmanned Flight.—The second Apollo/Uprated Saturn I space vehicle, AS 203, was successfully launched from Launch Complex 37 at Cape Kennedy on July 5. (Fig. 1–8.) Its purposes

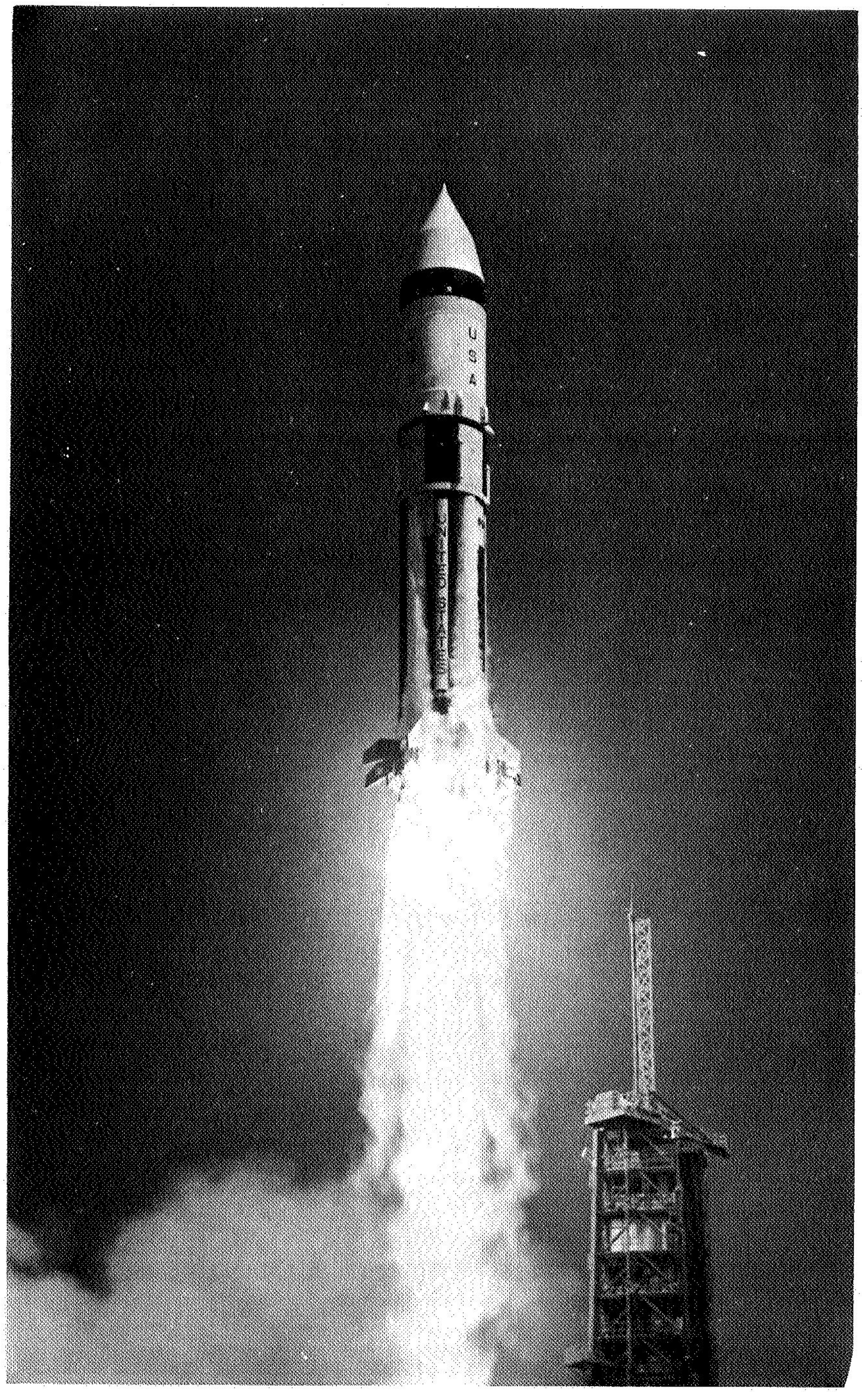


Figure 1–8. Apollo/Uprated Saturn 203 launch.

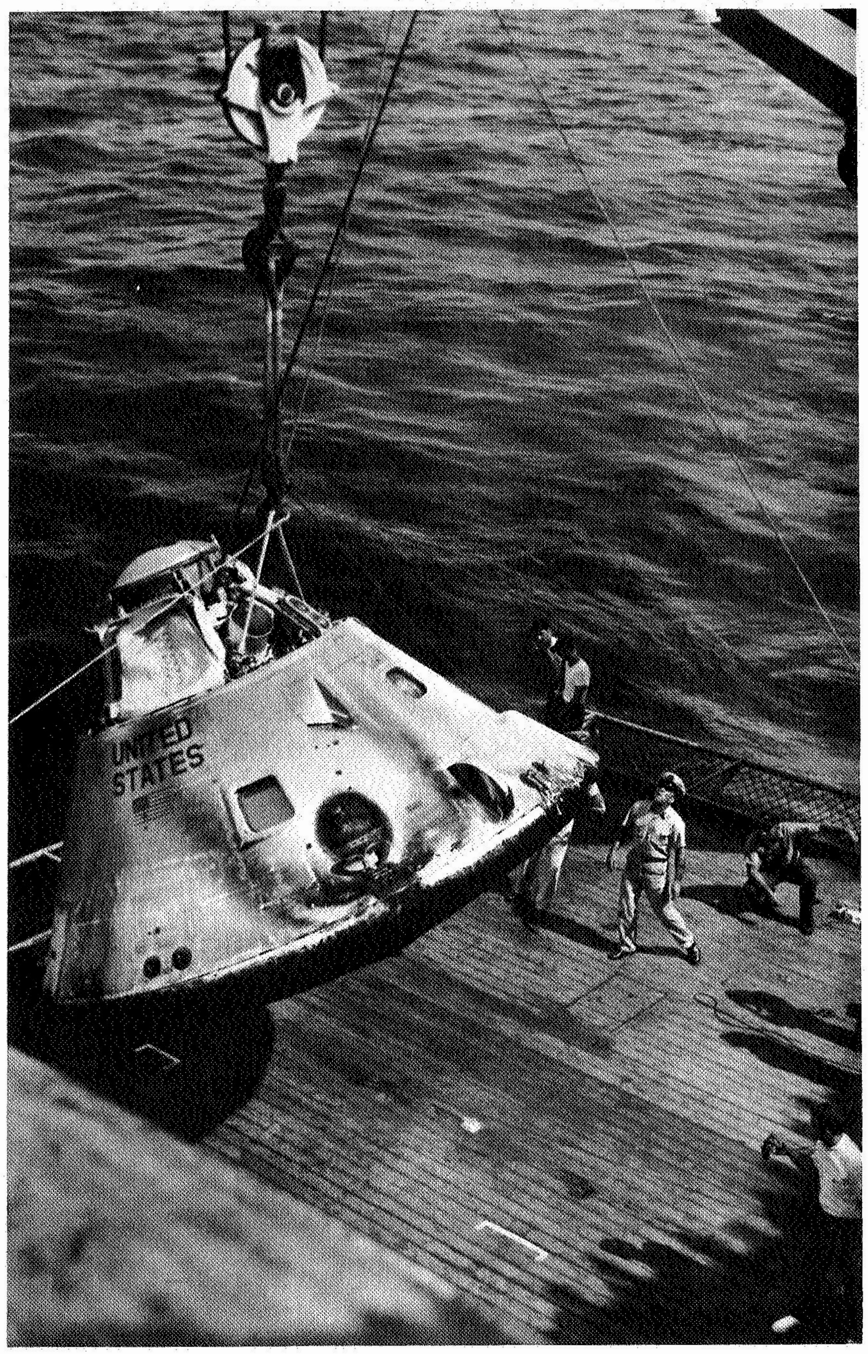


Figure 1–9. AS 202 Command Module recovery.

were to verify the Saturn V upper stage system performance and operation early in the Apollo program, to provide technological data on the behavior and management of liquid hydrogen in earth orbit, and to continue development of the space vehicle for manned flights.

The space vehicle consisted of an operational Uprated Saturn I first stage and a Saturn I second stage modified to simulate a Saturn V third stage configuration. The second stage was instrumented to obtain data on liquid hydrogen behavior. No spacecraft was flown on this mission. The second stage, Instrument Unit and nose cone represented the heaviest U.S. satellite ever placed in orbit, with a weight of approximately 58,500 pounds.

AS 202 Unmanned Flight.—The third Apollo/Uprated Saturn I space vehicle, AS 202, was successfully launched from Complex 34 on August 25. (Fig. 1–9). This unmanned suborbital flight terminated in recovery of the Command Module near Wake Island in the Pacific. The purpose of the mission was to demonstrate the performance of the space vehicle in preparation for manned orbital missions, and it showed that the Command Module heat shield was adequately designed for entry from earth orbital missions.

The space vehicle consisted of an Uprated Saturn I launch vehicle and a Block I Command and Service Module spacecraft with essentially all systems operational. This third and very complex mission was a major milestone in preparing for manned flight.

Program Hardware and Software

Space vehicle ground qualification and certification for flight were a major Apollo effort during 1966. Extensive and intensive qualification and test programs, involving thousands of tests, was conducted.

Ground qualification and flight certification for the Uprated Saturn I launch vehicle were completed in 1966, and similar efforts for the Saturn V launch vehicle were nearing completion. In the spacecraft area, the Block I Command and Service Module completed almost all of its qualification and certification testing, and qualification and certification testing of the first Block II Command-Service Module and Lunar Module were in progress.

Uprated Saturn I Launch Vehicle.—The three unmanned missions in 1966 verified the design of the vehicle and the use of liquid hydrogen as a fuel in the upper stage. In September, a design certification review board was convened to assess the design of the Uprated Saturn I for manned flight, and subsequently de-

termined the Uprated Saturn I launch vehicle to be man-rated.

Two first stages of the Uprated Saturn I were delivered to KSC and were being readied for flight in 1967, and the remaining seven flight stages were in various stages of fabrication, assembly, or checkout. Four are to be delivered to KSC during 1967 and the last three during 1968. Qualification of all first stage flight-critical components was completed during 1966.

During the latter half of 1966, two second (S-IVB) stages for the Uprated Saturn I were delivered to KSC for flights in 1967, and the remaining seven flight stages were in the pipeline. (S-IVB stages for the Saturn V were also in the pipeline. One Saturn V stage was delivered to KSC in August, and six others were in varying degrees of fabrication or checkout.)

Instrument Unit.—The Instrument Unit, common to both the Uprated Saturn I and the Saturn V, houses electrical and mechanical equipment which guides, controls, and monitors vehicle performance from liftoff to payload injection. (Fig. 1–10.) Ground qualification testing of nearly all Instrument Unit components was completed for both the Uprated Saturn I and Saturn V launch vehicles. The Instrument Unit successfully operated during the flights of AS 201, AS 203, and AS 202. As a result, there is high confidence in its flight performance. Two additional Uprated Saturn I units and the Instrument Unit for the first Apollo Saturn V were delivered to KSC.

Saturn V Launch Vehicle.—The first Saturn V flight vehicle, minus the second stage, was delivered to the launch site in August and September 1966. Nearly all of the major stage ground testing and the major portions of the components qualification were accomplished, and only a small portion of the qualification program remains to be completed in 1967.

The Saturn V 500–F vehicle was used to verify the operations and functions of the Saturn V launch facilities. (Fig. 1–11.) These included the Launch Umbilical Tower, the Mobile Service Structure, Launch Control Center Firing Room No. 1, and Launch Pad 39A at Launch Complex 39. This nonflight facilities checkout version of the Saturn V provided the necessary verification and valuable training before operations with flight hardware.

Component qualification testing was essentially completed for the Saturn V first stage, and reliability testing is to be completed by about mid-year 1967. The first flight article, S–IC–1, was delivered to Launch Complex 39 on September 7.

Acceptance test firings on the second and third flight stages of the first stage were successfully completed. S–IC–3, the third flight stage, was the first contractor-produced first stage to be static fired. Flight stage S–IC–1 was erected on Launch Umbilical

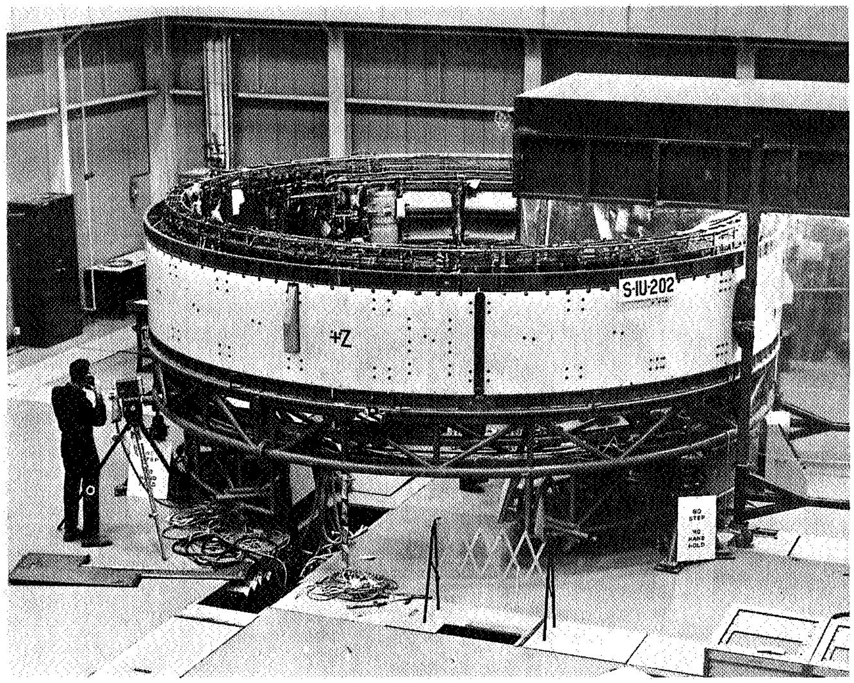


Figure 1–10. AS 202 instrument unit.

Tower No. 1 to begin checkout of the first Saturn V launch vehicle.

The S–IC All Systems stage was delivered to Mississippi Test Facility in October for checkout of the first S–IC acceptance firing stand at MTF. The stand checkout with the S–IC All Systems stage includes a static firing to be conducted in the first quarter of 1967.

Although the Saturn V second stage (S–II) continues to be the pacing item in the development of the launch vehicle, positive progress was made during this report period. Further confidence was gained from the manufacturing checkout results of the flight hardware and the two successful static firings of the first flight second stage at the Mississippi Test Facility in December. Along with the static firings of S–II–1, manufacturing checkout on S–II–2 was completed. The manufacturing checkout results of all the second stages processed to date—the S–II–T, S–II–1, and S–II–2—confirm the design of the mechanical and electrical/electronic systems.

Subsequent to the loss of the S–II All Systems Stage, as reported in the *Fifteenth Semiannual Report,* a second stage confidence improvement program was inaugurated to verify the design of this stage before committing it to flight. The confidence im-

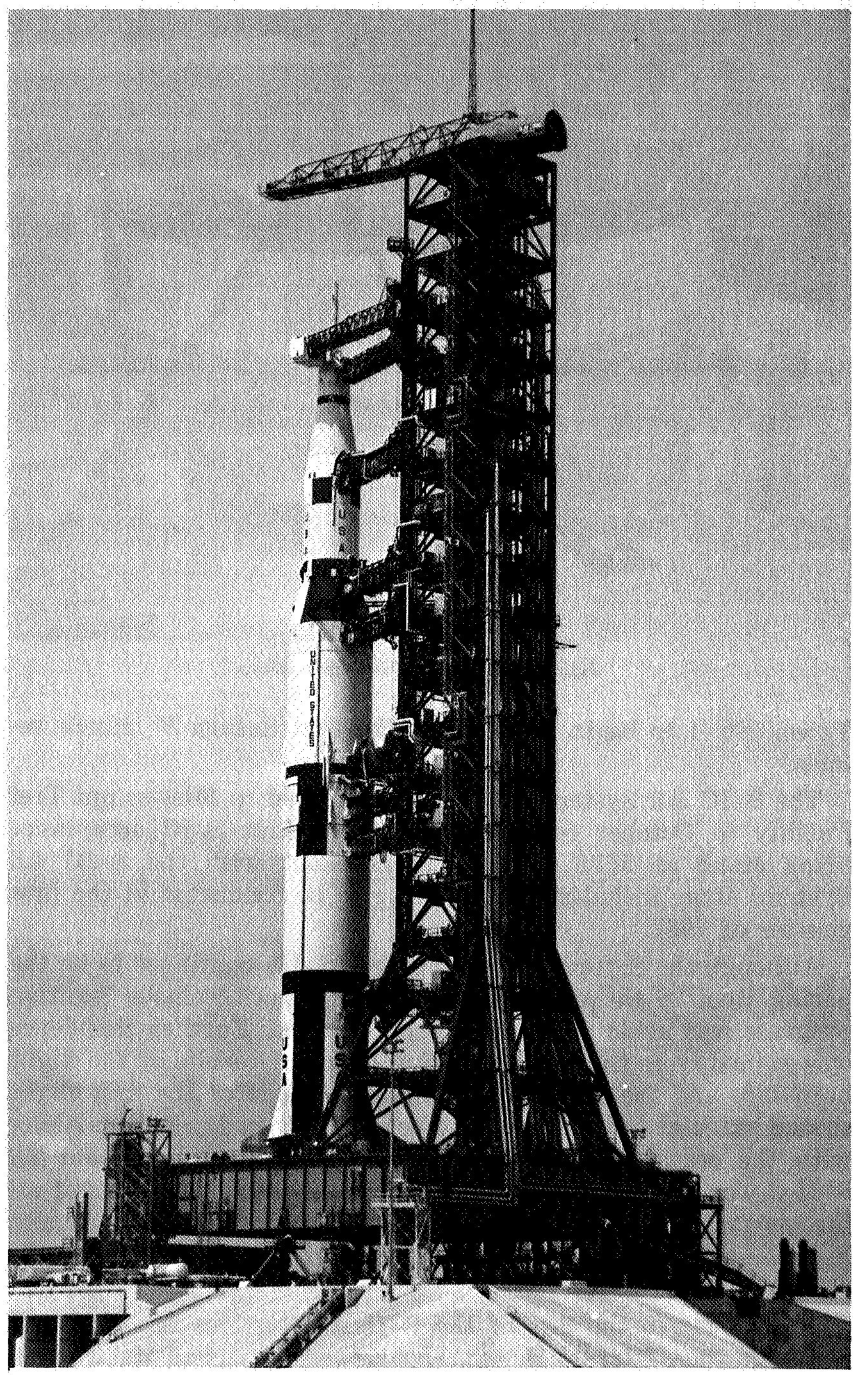


Figure 1-11. Saturn V 500-F.

provement program consisted of further test firings of the S–II battleship, as well as the S–II–1 and S–II–2 stages, before delivery to the launch area for integration into the first two Saturn V flight vehicles. (Fig. 1–12.)

After a careful review of the program requirements and available alternatives, the S–II Facility stage was assigned to the dynamic test program at MSFC. This resulted in a slight delay in the dynamic testing since the facility stage was being employed in the Saturn V 500–F facilities testing at KSC.

To minimize the impact at KSC of the delayed delivery of the S–II stage, an S–II "spacer," already available, was shipped to Cape Kennedy. This made it possible to stack the third stage and spacecraft for checkout purposes in the Vehicle Assembly Build-

Figure 1–12. The S–II stage.

ing. This inexpensive expedient will also be used to facilitate checkout of the AS–502 and AS–503 vehicles, if the S–II stage deliveries remain behind schedule.

The S–II stage also experienced cracking problems during the period. Small internal cracks were found in the ends of the vertical and horizontal ribs and in the five outlet ducts of the liquid hydrogen tank. These cracks result from forming and welding operations during the manufacturing process which creates residual stresses and the low ductility of the parent materials. Repairs were made on the stages already built, and changes in manufacturing methods were being made for stages still in fabrication.

Repair of cracks in the S–II–1 stage, which will be flown on the first Saturn V flight, delayed the acceptance firings at Mississippi Test Facility and the AS–501 launch preparation at KSC.

Repairs made to the flight hardware were verified through the use of the second stage common bulkhead test tank. Cracks in the tank were simulated and ground-down areas in the tank were reinforced with bolted-on patches. The tank was then subjected to cryogenic and hydrostatic tests. The results of these tests indicated that the repairs were successful.

The second stage thrust and aft stage structures were subjected to acoustic and vibration environment simulation. Additionally, stack tests were conducted to verify the design of the structural interfaces between the second stage and the first and third stages. Subsequently, the S–II–1 stage successfully underwent two full-duration acceptance-test static firings at MTF in December.

Saturn Launch Vehicle Engines.—Major development milestones were passed when qualification of the uprated J–2 and F–1 launch vehicle engines was completed in September. Flight worthiness verification testing of the uprated H–1 engine was continuing in support of manned Saturn I missions. H–1 production engine deliveries for the first stage of the Uprated Saturn I were completed in this period.

Qualification of the uprated J–2 engine whose thrust varies from 205,000 to 230,000 pounds, depending upon the fuel mixture ration, was completed in September. This uprated engine, used in the upper stages of both the Uprated Saturn I (effective on AS–207) and Saturn V (effective on AS–504), provides greater payload margins for these manned vehicles. (Fig. 1–13.)

The F–1 engine, now rated at 1,522,000 pounds thrust, completed qualification testing in September and is to be flown for the first time in the AS–501 vehicle in 1967. As a result of this uprating from its original 1,500,000 pound thrust, the total thrust of the Saturn V first stage is now 7,610,000 pounds. Fifty-one

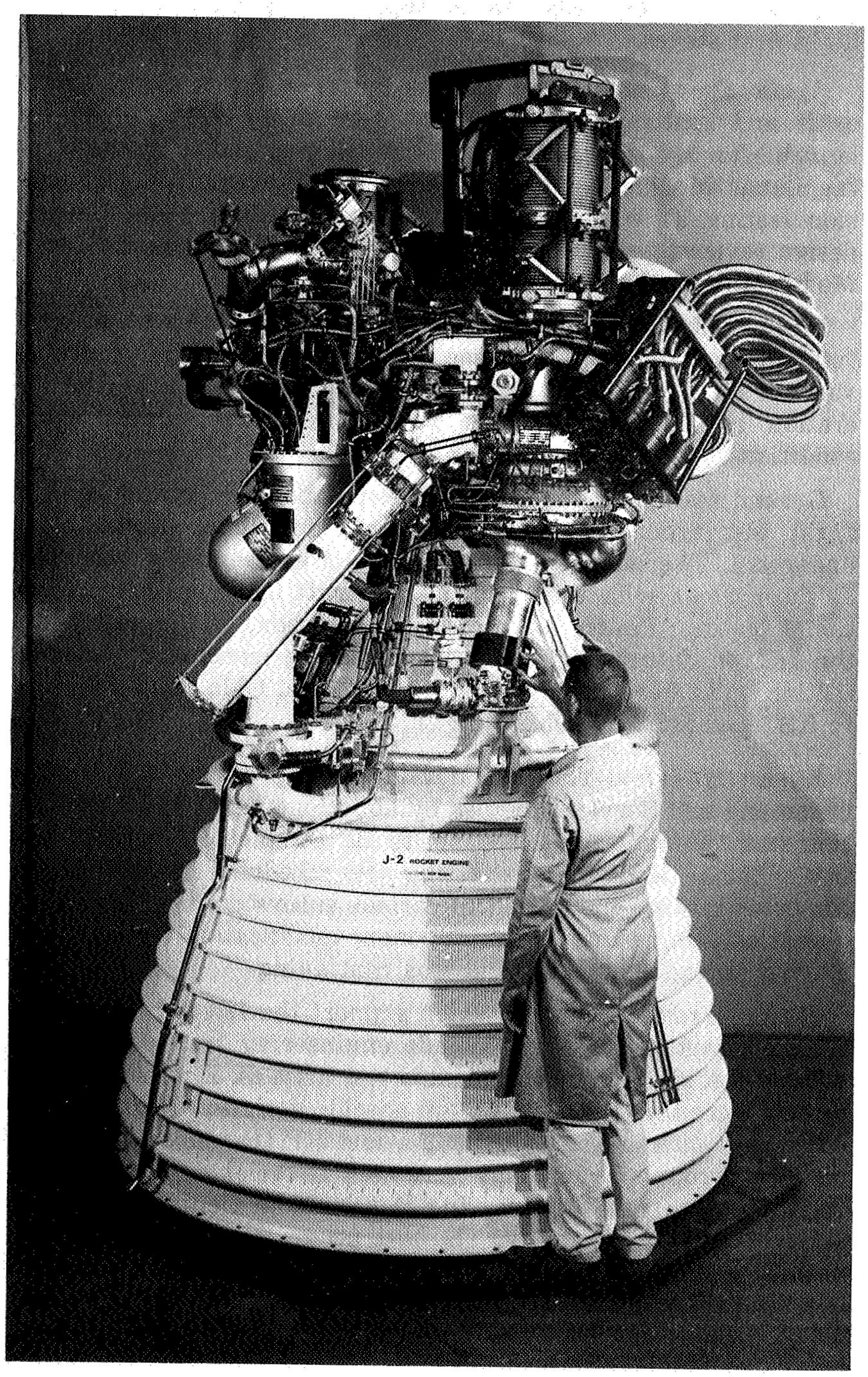


Figure 1–13. The J-2 engine.

engines have been delivered in support of ground testing and flight first stages.

Apollo Spacecraft.—As with the launch vehicles, flight spacecraft and spacecraft test articles were being delivered at the launch site. By the end of 1966, many of the ground tests for the Lunar Module flight were completed. Lunar Module propulsion testing at White Sands is to continue into 1967. Critical design reviews were conducted on the Block II Command-Service Module and on the Lunar Module.

In November, Command and Service Module 008 was successfully ground tested with three crewmen in the MSC thermal-vacuum facility. During the manned test of the vehicle, the operation of the systems was verified under simulated space conditions.

Ground testing of the Block II Command and Service Module flight test type spacecraft, configured for lunar flights, was underway. The adapters for Block II are essentially the same as those flown with the Block I spacecraft and require no additional testing. Testing of the adapter section, which will house the LM on future flights, was successfully concluded. Adapter section units were being fabricated at Tulsa, Okla., and delivered to KSC and MSC by helicopter.

Lunar Module.—The LM development program follows the Command and Service Modules by about one year, with qualification and major ground testing to be completed in 1967, and initial Lunar Module flight testing also scheduled in 1967. Major components were integrated in various subsystem tests and their operation was verified. The component qualification test program started during the period and was continuing.

Major hardware articles which support the LM subsystem and vehicle development effort include engineering test models, propulsion test rigs, and lunar module test articles. Engineering test models were being used to obtain specific design performance information such as thermal-vacuum and RF transmission characteristics. Propulsion test rigs were used at the engine contractor's facilities, at Arnold Engineering Development Center, and at the White Sands Test Facility. The test program on the ascent and descent engines at the Arnold center was completed, and supplemental testing was continuing at the engine contractor's plant.

Fabrication and assembly effort increased on a number of flight and test vehicles. The static and dynamic lunar test article, LTA–3, successfully completed its tests at MSC in November, and in the same month, the electrical integration test article,

LTA–1, completed tests. The thermal vacuum test vehicle, LTA–8, was undergoing final tests at the contractor's facility before being sent to the thermal vacuum chamber at MSC.

The first Lunar Module flight test article, LTA–10R, a refurbished ground test article, was delivered to KSC in September, thus achieving a significant milestone for Apollo. (Fig. 1–14.) The first flight Lunar Module, LM–1, which will be flown unmanned to demonstrate its propulsion and staging, was nearing completion at the contractor's plant.

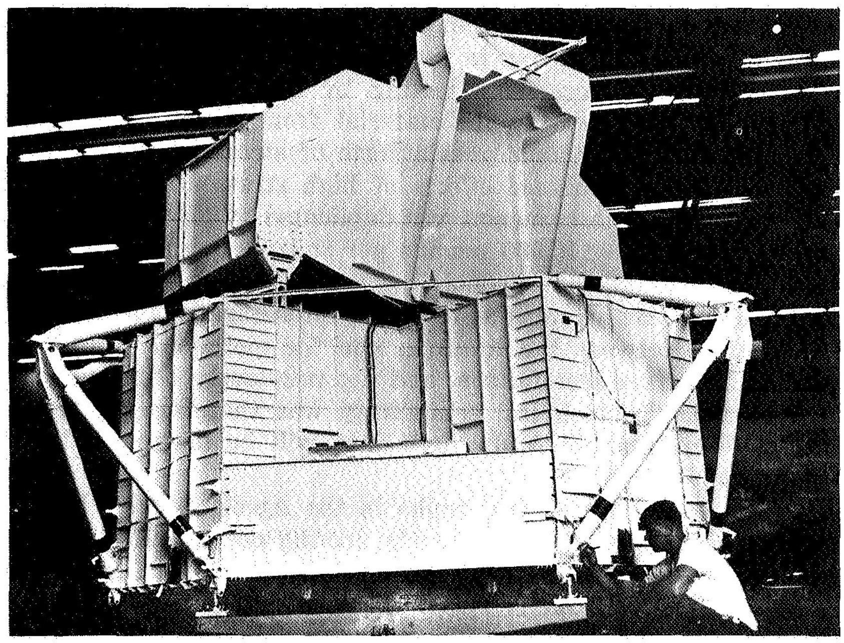


Figure 1–14. Lunar Test Article–10R.

In addition to the first and second Lunar Modules in the checkout phase, five other vehicles were in various stages of fabrication, assembly, and installation. Long lead procurement has been initiated on all of the remaining Lunar Modules.

Command and Service Module Development Problems.—The Apollo spacecraft Service Module contains four titanium service propulsion system tanks, two for the oxidizer and two for fuel. The problem of stress corrosion with the titanium propellant tanks and the nitrogen tetroxide oxidizer, which was reported earlier, was resolved by adding an inhibiting agent to nitrogen tetroxide. An extensive test program verified that a small amount of nitric oxide (less than 1 percent) effectively stops the corrosion and allows safe use of the tanks without a hardware change.

In late October, the titanium tanks in the Service Module of Spacecraft 017, planned for use on the first Apollo Saturn V flight, failed during pressure tests. Apparently one of the fuel tanks failed, and the shock wave from that failure destroyed another tank next to it. The tank was filled with methyl alcohol so as to avoid exposing test personnel to the toxic fuel. The tank that failed had been subjected to several pressure tests by the contractor and manufacturer at significantly higher levels of pressure than the pressure at which it failed. Thus, it was apparent that there had been a degradation in this tank in some fashion after successful completion of the more demanding tests.

From subsequent testing in the laboratories at Manned Spacecraft Center and secondary testing by the contractor, it was determined that the titanium material from which these tanks are made apparently undergoes a form of stress corrosion when subjected to the combined effects of high stresses and exposure to methanol. The phenomenon was duplicated by placing titanium under stress up to 140,000 pounds per square inch and exposing it to methanol—methyl alcohol.

Subsequent search of the technical literature confirmed that the reaction between the titanium and the methanol, discovered with the pressure test failure, had not previously been observed or recorded. The technical community was therefore alerted to this problem, and all future test data will be documented and made available.

As a precaution, the fuel tanks in the Apollo Service Module for flight AS–204 at Cape Kennedy, having been similarly tested but without failure, were replaced early in December.

Environmental Control Unit.—During qualification testing of the spacecraft Environmental Control System (ECS) in October, the porous plate for water distribution and filtering in the unit's water boiler, which provides cooling capacity in addition to that of the spacecraft radiators, became blocked. The problem was resolved by modification of the distribution plate.

Early in November, a modified ECS was placed in the Command and Service Module of the AS–204 space vehicle undergoing prelaunch testing at KSC, and some of the spacecraft tests previously accomplished at KSC were repeated. Spacecraft for all subsequent flights will use the modified ECS.

During checkout of the new Environmental Control Unit at KSC, leakage was detected in the water glycol system. The unit was returned for factory examination where a minor leak was discovered and corrected. After replacement in the spacecraft the Environmental Control Unit was successfully checked out.

In the LM descent and ascent engine work, problems delayed

the start of the qualification program. These problems were primarily erosion of the ablative engine throat and low performance. Corrections, involving changes in the injector design, were made and will be tested to verify performance of the propulsion systems.

The stress corrosion problem on the LM titanium propellant tanks in the presence of nitrogen tetroxide has been a problem in common with other titanium tank programs. As previously mentioned, an extensive test program resulted in a solution involving a change in the nitric oxide content of the nitrogen tetroxide. Methanol has not been used as a test fluid in the LM program and does not present a problem as it did for the CSM.

A potentially serious weight growth trend on the Lunar Module was overcome by a weight improvement program which has resulted in a continuing weight decrease. The vehicle now weighs less than design limits, and the weight margin can be used to advantage in loading additional propellant on board.

Checkout, Test, and Launch Operation Facilities

The stage checkout facilities to support the Saturn V program were being activated as planned. Static test stands and factory and post static test facilities became operational for the checkout of the first, second, and third stages, and the Instrument Unit.

The second factory checkout position for the Saturn V first stage was activated at the Michoud Assembly Facility near New Orleans in August and handled the factory checkout of the S–IC–4.

At the Mississippi Test Facility, work progressed toward operational status in early 1967 for both the second S–II static test stand and the first side of the first stage dual static test stand. (Fig. 1–15.) The second position of the latter stand is not to be activated unless required later in the program.

At MSFC, the Saturn V system development facility was being used to verify the operational capability of the launch vehicle checkout equipment and to develop and validate the checkout procedures and computer programs.

Spacecraft Factory Checkout Facilities.—During 1966, the CSM checkout capability was increased from three to four integrated test stands at the contractor's plant. The four stations were constructed as two sets of two stations each and share much common ground support equipment. Approximately 50 additional ground equipment units were required to support the checkout of the Block II spacecraft. Definition and manufacture of these new units were completed.

Four factory integrated test stands were activated at the LM

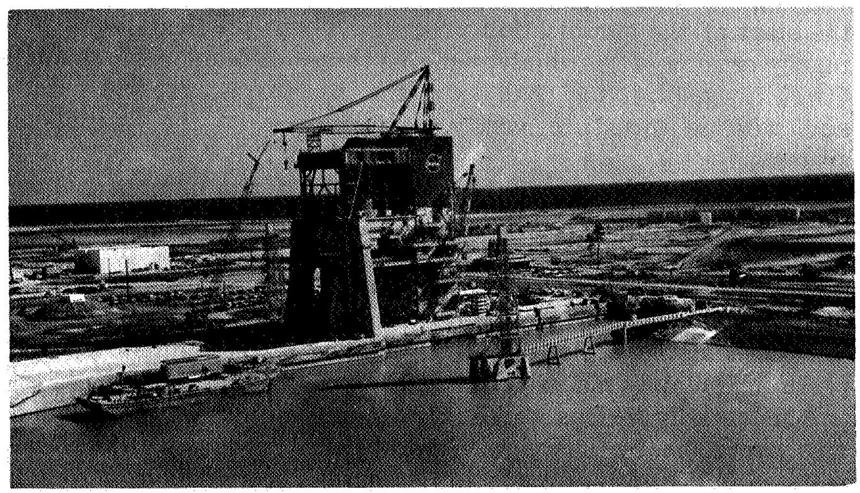


Figure 1-15. S-II Test Stand at MTF.

contractor's facilities. Three of these are to be used for acceptance checkout of completed LMs. The fourth, a wooden stand used for electromagnetic compatibility tests, will continue in use for house spacecraft developmental testing.

Spacecraft Checkout Facilities at KSC.—The industrial area facilities at KSC were activated for the Block I Apollo/Uprated Saturn I missions. Ground support equipment modifications will be required, however, for Block II Command and Service Module checkout at the propulsion static firing pad and in the altitude chamber and will take place by early 1967.

Launch Operation Facilities.—The Agency used Launch Complex 34 for two unmanned Saturn I launches, and it will also use it for the first manned Apollo/Uprated Saturn I mission. Launch Complex 37 was converted for Uprated Saturn I launches, and one was launched from it.

The Uprated Saturn I's are assembled on Launch Complexes 34 and 37 as the stages are received from the factory. The spacecraft modules are checked out in the industrial area at KSC before mating with the launch vehicle. Launch Complex 34 can currently assemble, check out, and launch the Saturn I with the Apollo Command and Service Module. When completely modified, Launch Complex 37 will be able to launch the Apollo/Uprated Saturn I with the LM.

After launch of AS-201, the umbilical tower at Launch Complex 34 showed signs of unusual stress. Architectural engineering study recommendations to reinforce the tower were carried out before the AS-202 launch, and no further stress problems were noted.

Construction of Launch Complex 39 for the Saturn V launch vehicle was well along, and the wet test of Pad A, using the 500–F vehicle, was completed. (Fig. 1–16.) Individual stage propellant and multiple simultaneous propellant loadings were demonstrated, proving the capabilities of Launch Complex 39 for the first Saturn V launch. The Crawler-Transporters, their bearing problems solved, performed satisfactorily in several moves of the Launch Umbilical Tower, both unloaded and loaded with the 500–F vehicle. Tests also were performed by moving the Mobile Service Structure to Pad A for a compatibility check with the Launch Umbilical Tower and the 500–F vehicle.

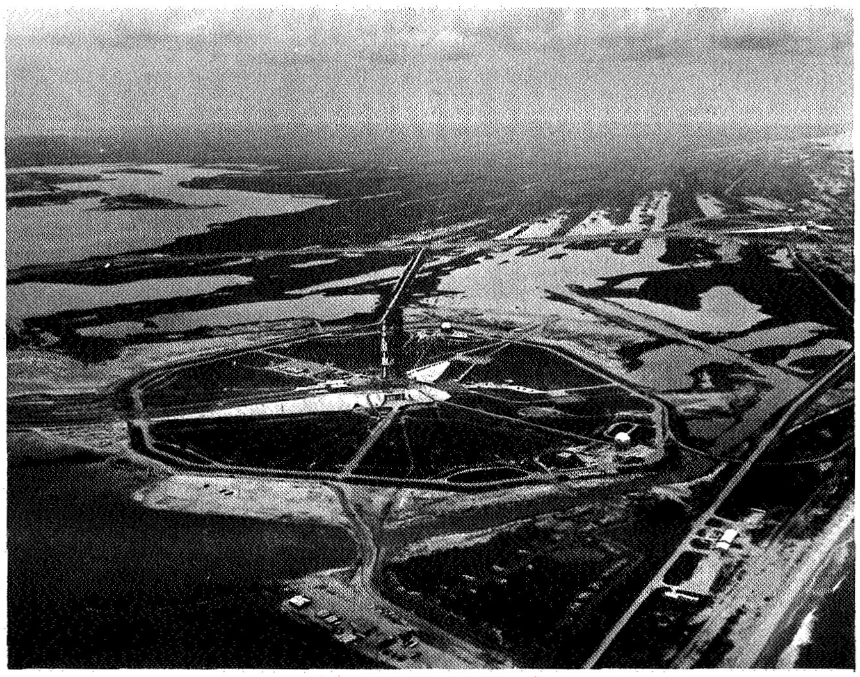


Figure 1–16. Launch Complex 39, Pad A.

Launch Complex 39 is to be fully operational in 1968, when three of its four high bay areas will be activated. The complex will have two Crawler-Transporters, three Launch Umbilical Towers, one Mobile Service Structure, two pads, and three instrumented firing rooms in operation. The Instrument Unit, the second stage, and the third stage can be modified in the low bay area of the Vehicle Assembly Building at LC–39. The entire Saturn V vehicle is erected on the Launch Umbilical Tower area before the move to the launch pads.

Software.—Following the delivery of operating systems and

test programs for AS–201, MSFC delivered on schedule the succeeding computer programs for AS–202, AS–203, and AS–204. Each new programming package has included software for automating additional test functions.

During the AS–201 checkout, the RCA 110A computers performed erratically. Subsequent investigation determined that abnormal stresses during heat cycling of the computer caused the solder to crack at the transistor leads on the printed circuit boards. Corrections were made, and 17,000 printed circuit boards in the RCA 110A computer performed satisfactorily during the launches of AS–202 and AS–203. The remaining 47,000 boards were reworked to support future missions. (Fig. 1–17.)

Figure 1–17. Computer Area, Launch Control Center.

Training of Personnel.—In connection with the extensive facility checkout operations of the Saturn V 500–F vehicle at KSC, which verified the mechanical and electrical interfaces of the systems, all launch support personnel received training and experience in handling large quantities of liquid oxygen and liquid hydrogen; in operating the Crawler-Transporter under load conditions; in operating cranes in the Vehicle Assembly Building (Fig. 1–18); and in carrying out the required assembly, checkout, and disassembly procedures associated with preparing the Apollo Saturn V space vehicle for launch.

Checkout Systems.—The checkout system for the Saturn V launch vehicle consists of seven computers, more than 1300 panels of electrical support equipment, and over 3000 cables to interconnect all this equipment. This system was manufactured, installed, and tested on schedule, and utilized for both the wet test of 500–F at LC 39 Pad A and the checkout of AS–501.

Computer Programs.—Major computer program problems were overcome and computer program tasks were completed on schedule. Computer programs for the wet test of 500–F at Pad A and for the checkout of AS–501 were developed and delivered.

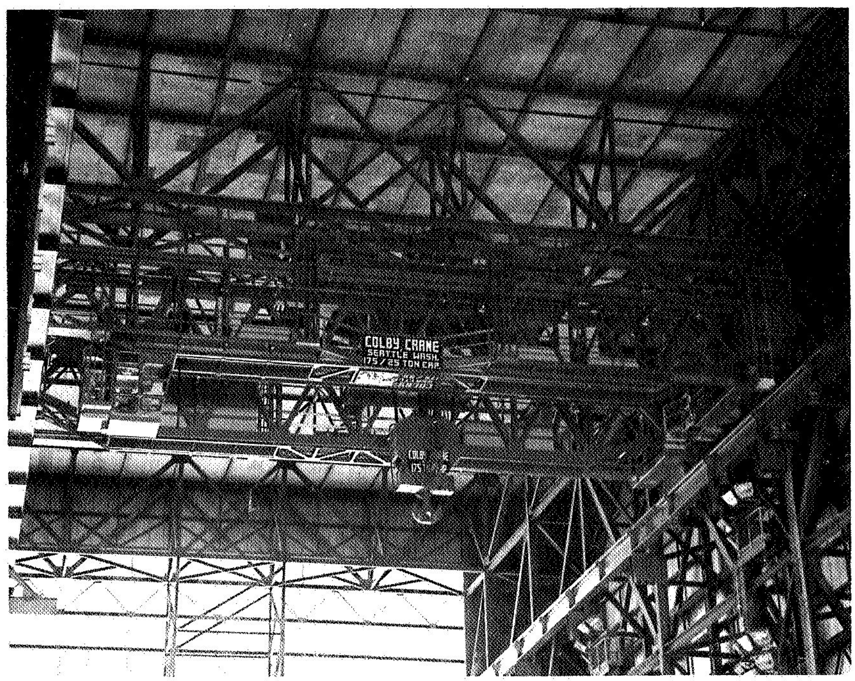


Figure 1–18. 175-ton bridge crane in VAB.

Launch Complex 39 Liquid Oxygen Propellant System.—A flexible section of an 18-inch liquid oxygen transfer line ruptured during a Pad 39A facility checkout test in August, and the 900,000-gallon-capacity liquid oxygen tank to which the line was attached discharged its contents. The tank's inner shell dimpled because of the resulting low internal pressure. The liquid oxygen discharge also displaced piping and caused minor damage to the tank foundations and nearby machinery. All damage was repaired, the system was modified to prevent a recurrence, and the tank was refilled in approximately one month.

Experiments.—As with the Gemini program, the accumulation

of experimental data in a variety of categories is an objective of Apollo. Experiments can be broken down into three areas of emphasis: in-flight, long-term lunar surface, and geological.

During the early part of the Apollo program, when earth orbital flights are being conducted to qualify systems for the lunar landing mission, spacecraft space and crew time will be available for conducting experiments, many of which, particularly in the medical field, will be expanded or improved versions of those conducted in the Gemini program. Others will be directed toward improved spacecraft design and operational techniques.

A number of new scientifically oriented experiments which are being introduced will conduct astronomical investigations not possible from under the earth's atmosphere or take advantage of the extended periods under zero gravity conditions.

The long-term lunar surface study is to be carried out by the Apollo Lunar Surface Experiments Package (ALSEP). (Fig. 1–19.) This is a self-contained package of technically advanced scientific instruments which the astronauts will place and leave on the moon to make measurements for one year or more after the astronauts depart. Passive and active seismic experiments, lunar heat flow experiments, and solar wind and charged particle lunar environment experiments are some of the major items. Electric power for controlling the experiments and transmitting data to earth will be supplied by a radioisotopic thermoelectric generator.

The lunar geological experiment is designed to make maximum use of the astronauts as geological observers. It will involve selecting lunar samples, photographing the sampling sites, and packaging and returning the samples to earth where they will be useful for biology, geochemistry, geophysics, and other scientific studies.

Logistics.—Development of the Apollo Saturn logistics base during the past year resulted in identifying and implementing the various elements of the support program as they apply to the mission. The Apollo logistics requirements plan, establishing the principles of the logistics base, became the guideline and evaluation medium for the manned space flight centers and contractors.

Based on an agreement in 1966 between the Air Force and NASA, the Air Force Logistics Command will procure, distribute, and manage certain propellants and pressurants for both agencies under the single manager concept. This support will be provided at certain locations to improve the economy and efficiency of operations.

In the area of marine shipment of Saturn items, five Uprated Saturn I stages were transported by barge from Huntsville,

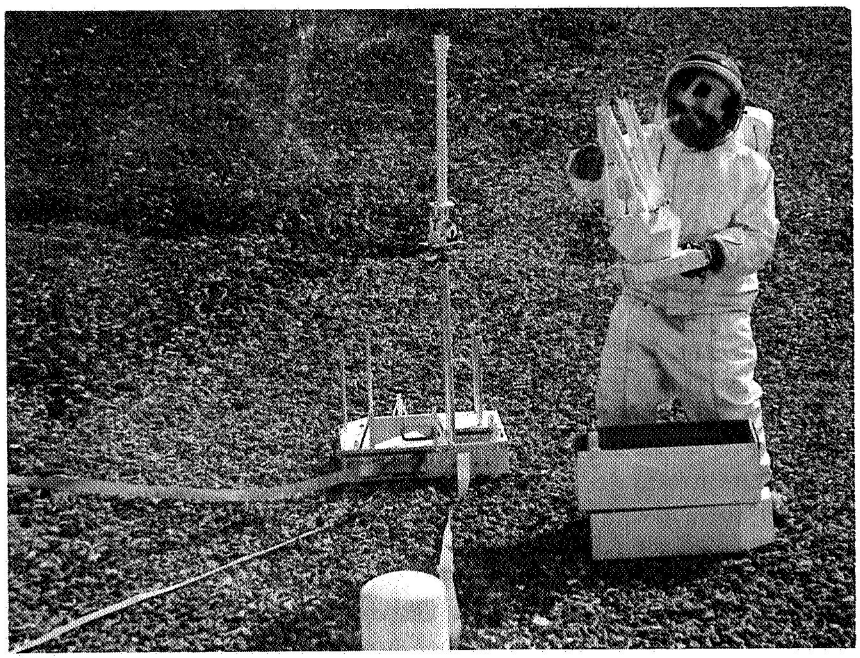


Figure 1–19 Apollo Lunar Surface Experiments Package.

Figure 1–20. S–IC stage and transport barge.

Alabama to KSC. Additionally, the specially converted USN ship, *Pt. Barrow,* which the Department of Defense provides to NASA on a cross-servicing agreement to reduce shipping costs, delivered the first stage of the Saturn V from Michoud to KSC. (Fig. 1–20.)

Three second stages for the Uprated Saturn I were delivered from California to KSC, using the Super Guppy Aircraft. This

aircraft, an Air Force C–133B, and military helicopters have previously delivered major Saturn/Apollo/Gemini end items: Apollo Command Modules, Service Modules, and heat shields; Lunar Module Adapters; Saturn Instrument Units; Lunar Module Test Articles, mockups, and simulators; F–1 engines; and Gemini spacecraft and launch vehicles.

ASTRONAUT STATUS AND TRAINING

During the period, the number of assigned astronauts was increased from 31 to 50. Three of these were in management positions, and the remaining 47 were either undergoing general training or were available for crew assignments. Three scientist/astronauts graduated from pilot training at Williams Air Force Base in July, giving NASA five scientist/astronauts who are also fully qualified as pilots.

Nineteen new pilot astronauts reported to NASA in July. The five previously chosen scientist/astronauts and the 19 new pilot astronauts are providing valuable support in the development of experiments, flight hardware, and operational procedures as they continue training to achieve flight-ready status. Particularly significant is the fact that Gemini missions increased the total number of flight experienced astronauts to 17, providing an excellent base on which to build Apollo flight crew experience.

Gemini Training

At the beginning of the period, 23 pilot astronauts had either made space flights or were extensively trained for the Gemini Program. These crewmen required only refresher training for those in-flight operations that were repeated from previous missions. Consequently, they were able to devote considerable training time to Apollo tasks.

Rendezvous and docking were given a great deal of attention, and the Gemini in-flight successes in this area can be attributed largely to thorough planning and good training. Also, special attention was given in the Gemini X, XI, and XII flights to extravehicular activity. The use of under water zero "g" simulations for developing procedures and training crews proved to be very effective. The experience gained by the crews and the in-flight techniques developed will be invaluable in planning and continuing Apollo lunar missions.

Apollo Training

During July, August, and September, while Apollo simulators

were being worked on, engineering simulators at contractor facilities were used extensively for refining crew procedures and for crew training. By taking these temporary measures, NASA had well trained crews available on schedules consistent with those for spacecraft delivery and launch preparation.

The first lunar module simulator (LMS) was delivered to MSC in October, and work began immediately to configure it for the first manned mission involving LM rendezvous operations. (Fig. 1–21.) Immediately after the Gemini XII flight, Gemini simulators and training equipment were made available to the contractor for conversion to Apollo use. The Gemini mission simulator at MSC is to be converted into an Apollo trainer which can simulate a considerable part of the lunar mission.

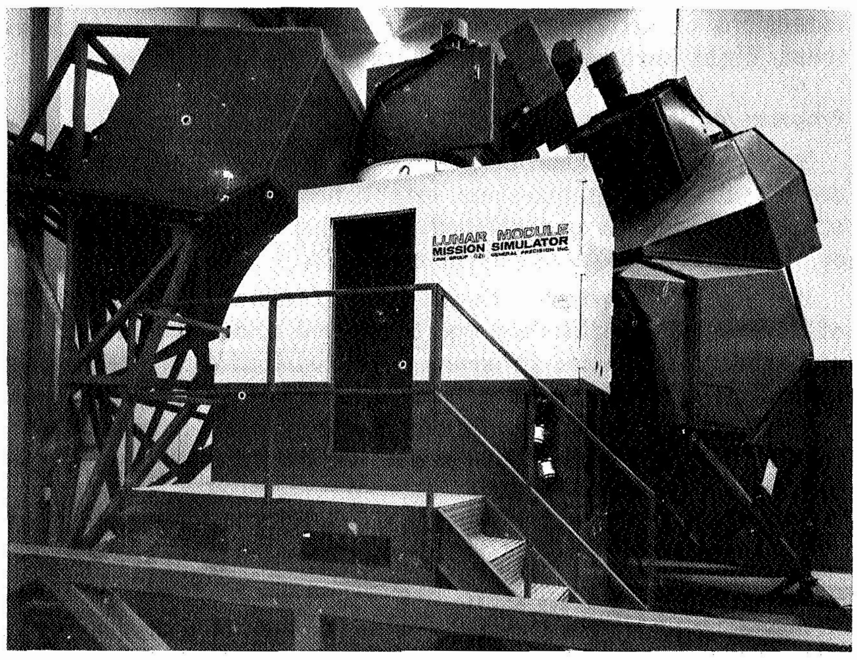


Figure 1–21. Lunar Module Simulator.

In December, the lunar landing research vehicle (LLRV) R&D program was completed at Edwards Air Force Base and the two LLRVs were moved to Ellington Air Force Base, Texas. Work began in December on a maintenance and operation site located on one of the unused taxi strips at Ellington. When this facility is completed, the LLRVs will be used for initial dynamic flight training of the flight crews for the final lunar landing phase of the lunar mission.

New Astronaut Selection

In September, the second scientist/astronaut selection program was initiated. At NASA's request, the National Academy of Sciences undertook the recruiting and scientific screening phase of the selection program. The response was excellent, with more than 800 applications on hand by the end of December. The National Academy of Sciences will complete its scientific screening of candidates by March 15, 1967, and NASA is to make final selection during the following summer.

APOLLO APPLICATIONS

Program accomplishments during this period were essentially extensions of activity previously reported in program management, flight hardware, experiments, and flight missions.

Program Management

Previously established program objectives were more carefully defined. Project organizations, established earlier at the manned space flight centers, continued to add personnel and develop competent project management capability.

Revision of the program development plan was initiated, a draft of the program specification was completed, and a draft reliability and quality assurance program plan distributed to the project organizations at MSFC, MSC, and KSC. The first Apollo Applications Configuration Control Board was convened. Meanwhile, further steps were taken to define the configuration of flight hardware.

Flight Hardware

Efforts were underway to develop selected flight hardware items. A contract was awarded for the airlock module which will permit the Uprated Saturn I second stage to function as an orbital workshop, and a preliminary design review was conducted at the contractor's facility. A new orbital workshop configuration was defined to include provision for a multiple docking adapter, and modifications were started on the S–IVB stage to adapt it for orbital workshop missions. Development of the Apollo Telescope Mount was approved and a configuration selected, (Fig. 1–22.), and the Apollo-developed lunar mapping and survey system configuration for Apollo Applications was selected. Procurement of long lead hardware items for Uprated Saturn I launch vehicles was started.

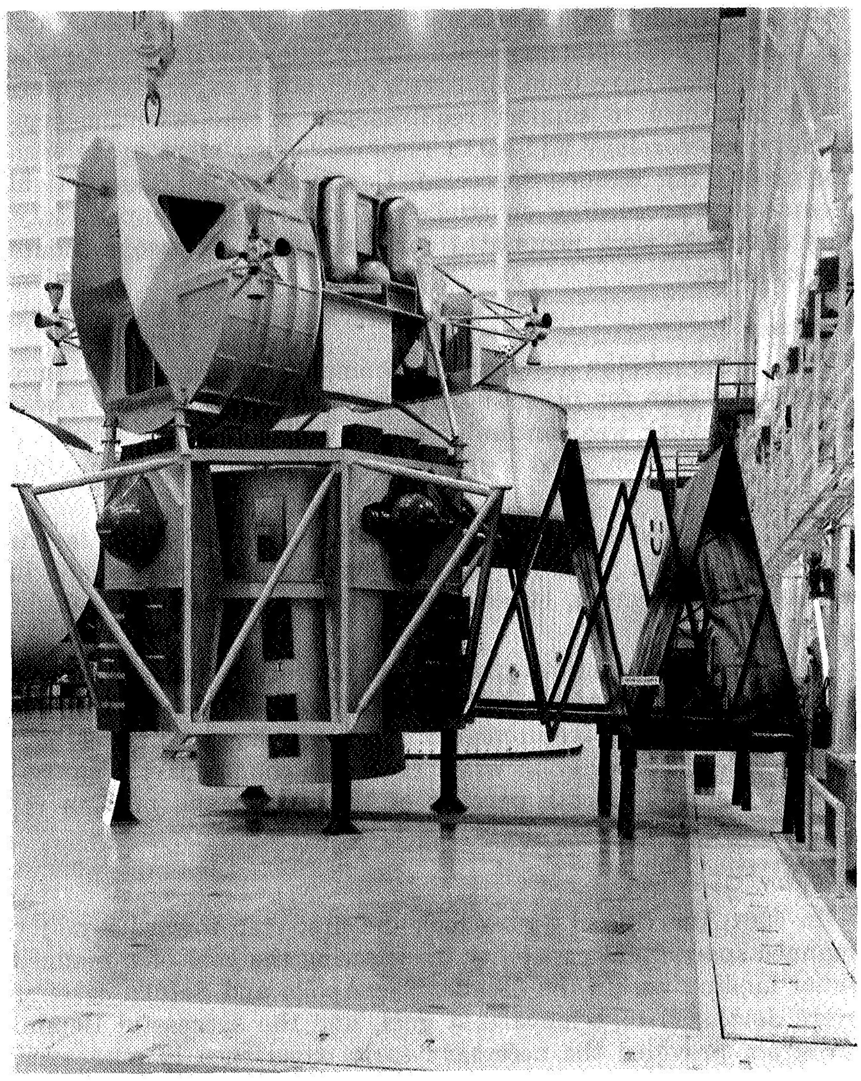


Figure 1–22. Apollo Telescope Mount and solar panels.

Studies were completed on requirements for a third-burn capability for the S–IVB stage, while other studies concerned the possible use of the C–1 engine for Apollo Applications and the status of fuel cell development and testing. Work continued on test planning for Apollo hardware items that would have to be modified or further qualified for use in Apollo Applications missions.

Experiments

As a result of planning activities noted in the last report, some

thirty-eight identified experiments were assigned to Apollo Applications for development. Substantially all experiments for the initial mission have been approved, and other experiments were being identified to support requirements of the scientific community. Meteorology and earth resources experiment areas were assigned to the Manned Spacecraft Center, Marshall Space Flight Center was proceeding on studies of experiment compatability, and contracts were negotiated for the Apollo Telescope Mount experiments.

Missions

The flight mission assignment document detailing the mission assignment plan for the first two Apollo Applications flights was published. Work was continuing on a mission plan for the third and fourth missions, and a preliminary document was issued for review.

The AAP mission planning task force convened early in the period to confirm plans for the first dual-launch missions, and in a subsequent meeting, began definition of the second dual-flight mission.

The mission operations program organization was formalized, and work was proceeding in the areas of mission planning, operations, and support requirements. This activity was being conducted in close association with the Apollo counterpart organization to insure a smooth phasing of the launch and mission requirements of the two programs.

Program Objectives

In 1961, the United States took the first step toward a major manned space flight capability by selecting the goal of a manned lunar landing within the decade. The Apollo and Saturn systems were developed to achieve that goal, and the successful Gemini Program provided the necessary early experience in maneuver, rendezvous, docking, extravehicular activity, and 14-day flight.

The Apollo Applications Program is the second significant step toward that capability and represents an effort even more important and far-reaching in its implications than the Apollo project upon which it is based. The program will carry out a full investigation of how man can effectively exploit the environment of space.

Specific objectives of Apollo Applications include the following: placing in orbit, in 1969, experiment-carrying modules for reuse in the following year; obtaining the maximum yield of solar data during the 1969–1971 solar maximum; conducting manned flights of up to 56 days, with a 3-man crew, in 1969; successively increas-

ing the duration of manned flights, up to one year, with 3 to 6 men in 1970; conducting medical experiments during such long-duration manned flights; developing land landing capability and increasing spacecraft crew capacity (up to 6 men) by 1970; making detailed multi-spectral surveys of the lunar surface from lunar orbit; carrying out extended lunar surface exploration missions of up to two weeks in 1971; and obtaining the maximum amount of science, applications, and technology experiment data possible during these series of flights.

ADVANCED MANNED MISSIONS

The Advanced Manned Missions program is responsible for overall systems engineering, planning, and definition of all advanced manned space flight mission studies and projects. It is also responsible for technical feasibility studies of major alternatives or additions to approved manned space flight mission projects. This work involves identification of mission requirements and modes for accomplishment, conceptual hardware design, identification of resource and technology requirements, and integration into overall programs to meet a variety of constraints.

While individual studies continued during this period, the main activity was directed toward mapping the course of manned space flight following the Apollo lunar landing. Immediate follow-on plans are the responsibility of the Apollo Applications program, which Advanced Manned Missions assisted. In addition, Advanced Manned Missions managed an intensive review of past studies in lunar and planetary exploration and participated in a NASA-wide effort concerned with planning for future manned space flights.

The latter effort was directed by a NASA-wide Planning Coordination Steering Committee formed for the purpose. To ensure adequate depth, the review and working groups of this committee were staffed by key technical and management personnel from NASA headquarters and from the field centers. Consultations were continued and intensified between NASA and other interested groups including Congressional staffs, the President's Science Advisory Committee, the Science and Technology Advisory Committee, the Space Council, and the National Academy of Sciences.

Evolutionary Program

Although no firm plan extending beyond Apollo Applications

resulted from these endeavors, a promising evolutionary program was outlined. This program incorporates a number of relatively small incremental advances, each of which can be evaluated on its own merits. Thus, commitment to any given incremental option does not involve commitment to follow-on options. More importantly, long-range, high-risk commitments to major undertakings such as earth-orbiting space stations, lunar bases, or planetary landings are not required to justify intermediate steps along the way. The selection of these long-range options is always possible, however, unless the line of progress toward them should be intentionally shut off.

Within the conceptual framework of step-by-step advances, it appears possible to plan programs responsive to new discoveries and changing national requirements with a minimum of wasted motion and expenditure. The programs are conceptually similar, differing in pace, annual cost, and degree of sophistication. This overall approach is now furnishing guidance for more detailed advanced studies which will yield increasingly realistic designs, schedules, and assessments of resource requirements. The broad objectives are exploration of the moon and planets, the advancement of science, application of achievements to life on earth, and contributions to national security.

Future Manned Space Flight Program

Possible missions which fit the Advanced Missions conceptual framework and criteria begin in the Apollo Applications program, using modified Apollo hardware. The spacecraft is modified for longer duration missions in space, and the Lunar Module is modified for longer missions on the moon's surface. An unmanned Lunar Module can be used as a transport for supplies and equipment in conjunction with a manned flight to increase stay-time up to 14 days and provide increased exploration capability as well. With modest improvement, the Uprated Saturn I and Saturn V launch vehicles provide adequate capability for Apollo Applications missions.

The next step in improved earth-orbit capability involves the in-orbit conversion of a spent Saturn vehicle upper stage into a habitable module. An airlock between an Apollo spacecraft and the spent S–IVB stage provides electrical power and the environmental system, a tunnel for crew transfer between spacecraft and stage, and a port for exit to space for extravehicular activity. Logistics resupply flights could keep this system with a crew of 3 or 4 going for 90 days or more. By stripping the S–IVB stage of propulsion systems and outfitting it on the ground, a one-year workshop mission with crew size of 8 or 9 becomes feasible.

Apollo Applications earth-orbiting systems design and operating experience will make it feasible in the 1970's to launch earth-orbiting space stations designed for 5 years of continuous operation with crews of 9 to 12 men. Several space station concepts which fit into the evolutionary program were examined during this period. They embrace a reasonable set of alternatives for follow-on to the Apollo Applications workshop, but differ in sophistication, ability to accommodate conflicting requirements, and cost. Some of the configurations could provide artificial gravity should that be necessary or desirable, and all could be launched by Saturn V vehicles. No attempt is being made to select from these now. Rather, design refinement of all is being continued so that a realistic set of options will be available by the time a decision on space station development is required.

Advanced mission studies conducted to date point to the space station as the key to future exploration and exploitation of space. It is here that earth-oriented applications in communications, meteorology, oceanography, and land resources could be made and subsystem refinement take place. Basic research in bioscience, medicine, and especially astronomy would benefit from the availability of larger, more sophisticated facilities than possible with preceding hardware. The five-year station envisaged for the 1970's offers ample opportunity for subsystem development, resolution of possible human factor problems, and spacecraft module qualification. These would be significant in meeting the technology and operational requirements for planetary exploration, for lunar orbiting stations, for larger space stations, or for more specialized space stations.

From current Advanced Manned Mission studies, it appears technically feasible to launch a manned reconnaissance mission to Mars in the late 1970s. Manned landing would not yet be possible, but several unmanned probes and impacters could be deployed and provision could be made for return of a soil sample to the manned spacecraft. The mission would last about two years, but it would return a wealth of valuable scientific data as well as other data pertinent to the design of an eventual manned landing mission. Commitment to such a mission would require long duration qualification of the crew quarters module as an earth orbiting space station in the early 1970's.

Apollo and Apollo Applications missions provide for lunar exploration in the vicinity of the landing sites. Results from these programs may indicate the desirability of more extensive surface installations and greater surface mobility. Preliminary designs of the required transportation system and of an extended mobility vehicle (MOBEX) were being worked on. The MOBEX design

is based on present knowledge of the properties of the lunar surface and could support a 3-man, 1,000 km, geological surveying party for 90 days. The design will undergo modification and refinement as more information becomes available.

The need for significant uprating of the Saturn V launch vehicle is also indicated by the advanced lunar and planetary mission studies. Various methods for uprating the vehicle were also the subject of intensive investigation. Improved engines, strap-on solid motors, high pressure engines, and increased propellant capacities were being studied singly and in combination.

SUPPORTING INFORMATION SYSTEMS

During the period, NASA improved and upgraded the capabilities of certain information and documentation systems which are necessary to provide data, communication, and record-keeping support for the Apollo program.

Launch Information Systems

The manned space flight project for developing, implementing, and operating ground instrumentation systems at the Kennedy Space Center during countdown, launch, and the initial phase of flight is known as Launch Information Systems.

Launch Information Systems includes the technical equipment necessary to collect space vehicle data directly from the vehicle on the pad or in early flight and assemble the data into proper format for transmission to the Mission Control Center, Houston, Texas, and to the Huntsville Operations Support Center, Huntsville, Alabama; to perform real-time computation on prelaunch checkout and launch data, providing "quick-look" data for engineering analysis; to provide a means of displaying these data to operational and engineering personnel; and to detect hazardous conditions in the launch area, minimizing the risk of injury to personnel and damage to equipment. During this period, the Launch Information Systems supported AS-202 and AS-203.

Space vehicle data are supplied to the MSC Mission Control Center in real-time by the Apollo Launch Data System. Launch vehicle data are supplied to MSFC in real-time during major preflight tests and launch over the Launch Information Exchange Facility (LIEF). LIEF provides data to the Huntsville Operations Support Center so that the many scientific personnel employed there may advise KSC and MSC operational personnel without having to leave their normal place of work. These data systems are operational and are being used to support Uprated Saturn I and Saturn V prelaunch checkout and launch.

Installation of Launch Information Systems equipment at

Launch Complex 39 for the support of Saturn V prelaunch checkout and launch operations progressed extensively, with completion expected in 1967. Equipment installed to support the first Saturn V launch (AS–501) includes large-screen display equipment, hazard monitoring systems, and geophysical measuring systems.

The computer complex in the Central Instrumentation Facility was expanded in December by installing additional GE–635 computer components. These additions enable the computer complex to support dual launch operations, such as are planned during 1967, and to provide computation back-up during critical single launch operations. In addition, the complex is used to process checkout and flight data; to prepare computer programs; to maintain stock records, schedules analysis, security, and payroll data; and to perform other administrative data processing functions.

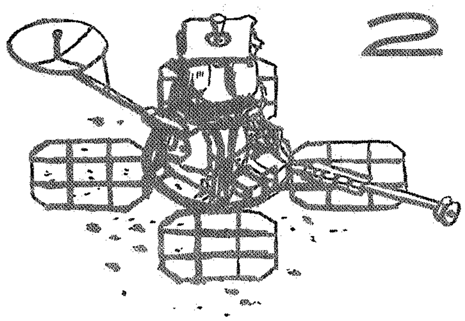
Mission Control Systems

During the period, the Mission Control Center at Houston (MCC–H) provided mission simulation, premission testing, and real-time flight control for Apollo Missions 202 and 203, and for Gemini Missions X, XI, and XII. Major modifications were completed during this time, the most significant being the installation and checkout of three IBM 360–75 computers. The more powerful 360–75s replaced IBM 7094 computers and provided the additional capability necessary for processing, displaying, and analyzing the greatly increased volume of data from Apollo missions.

The Simulation, Checkout, and Training System was updated with Apollo-type training hardware and a larger 360–75 computer to handle the increased data demands. The modifications to the Communications, Command, and Telemetry System, necessary to accommodate increased Apollo data handling requirements, were also completed with the installation of three UNIVAC 494 computers, together with interface and signal switching equipment. A prototype of a new Digital Television Converter System was delivered, and system testing was started. This system will significantly aid in preparing, storing, and displaying (real-time) mission operational data.

NASA/DOD Manned Space Flight Support Requirements Documentation System

The joint NASA/DOD Manned Space Flight Support Requirements Documentation System evolved gradually during the Gemini Program and the early stages of Apollo documentation. It now is an improved method for identifying manned space flight operations needs and for committing support organization resources to meet these needs. It is a common source of information for all planning organizations and permits early identification of support resources deficiencies, working interfaces, and conflicts.



2 SCIENTIFIC INVESTIGATIONS IN SPACE

NASA made noteworthy progress in this area of activity. Two Lunar Orbiter photographic laboratories and a Surveyor spacecraft transmitted thousands of clear pictures of the moon's surface, among them views of potential landing sites for astronauts. Two geophysical satellites simultaneously studied phenomena in interplanetary space near and away from the earth. The first Biosatellite was orbited in December to investigate the effects of space on various life forms. And results of experiments carried out during the Project Gemini manned flights further demonstrated the unique role of astronauts as sensors, manipulators, evaluators, and investigators in space, first evident from the earlier Project Mercury missions.

PHYSICS AND ASTRONOMY PROGRAMS

Explorer XXXIII

In these programs, NASA launched two satellites—Explorer XXXIII (July 1) and Pioneer VII (August 17). Explorer XXXIII, an Interplanetary Monitoring Platform, studies phenomena in interplanetary space near the earth. In orbiting the earth (apogee 295,900 miles; perigee 25,300 miles) it measures the magnetic field, examines the solar wind plasma of electrons and protons, and studies cosmic radiation. The satellite's experiments were working well. For example, data which they provided showed for the first time that the tail of earth's magnetosphere extends more than 75,000 miles away from the sun beyond the lunar orbit.

Pioneer

Pioneer VII studies phenomena in interplanetary space away

from the earth. A tiny planet of the sun, it travels in an orbit slightly greater than that of the earth. In this orbit it moves between 1.01 and 1.125 times as far from the sun as the average distance of the earth. Although the satellite weighs only 140 pounds, it is able to carry experiments to study magnetic fields, cosmic rays, and the solar wind. Pioneer VI—the companion to Pioneer VII launched inside the orbit of the earth on December 16, 1965—has discovered that:

.The lines of flow of the solar winds are curved and not straight;

.The average density of electrons (and hence hydrogen protons) in interplanetary space is 80 to 200 particles per cubic inch;

.The singly-charged helium ion is present in interplanetary space; and

.Solar cosmic rays flow in well-defined streams channeled by magnetic fields.

Sounding Rockets

Sounding rockets continued to carry experimens 100 miles above the earth and its atmosphere; in August their range was extended to 300 miles when the Aerobee 350 rocket was tested successfully.

The STRAP *S*tellar *Tr*acking and *A*ttitude *P*ositioner) stabilizer for rockets was developed and made accurate enough to allow astronomers to point instruments on the rockets at the planets and stars for observations of X-rays and ultraviolet radiation.

LUNAR AND PLANETARY PROGRAMS

Surveyor

Scientists and engineers who evaluated data provided by Surveyor I, including 11,237 high quality pictures of the lunar surface in the vicinity of the spacecraft, found that it landed on a dark, relatively smooth, barren surface encircled by hills and low mountains (*15th Semiannual Report,* p. 49.) Fig. 2–1 is a closeup of a Surveyor footpad and the disturbed lunar material around it. The material ejected by the footpad is made up of lumps, probably consisting of grains much too fine for the TV camera to photograph. These lumps show that the fragmented material on the surface is at least slightly cohesive. The spacecraft's footpad sank 1½ to 3 inches below the undisturbed surface, and strain gages on its landing gears determined a dynamic bearing strength of 6 to 10 pounds per square inch.

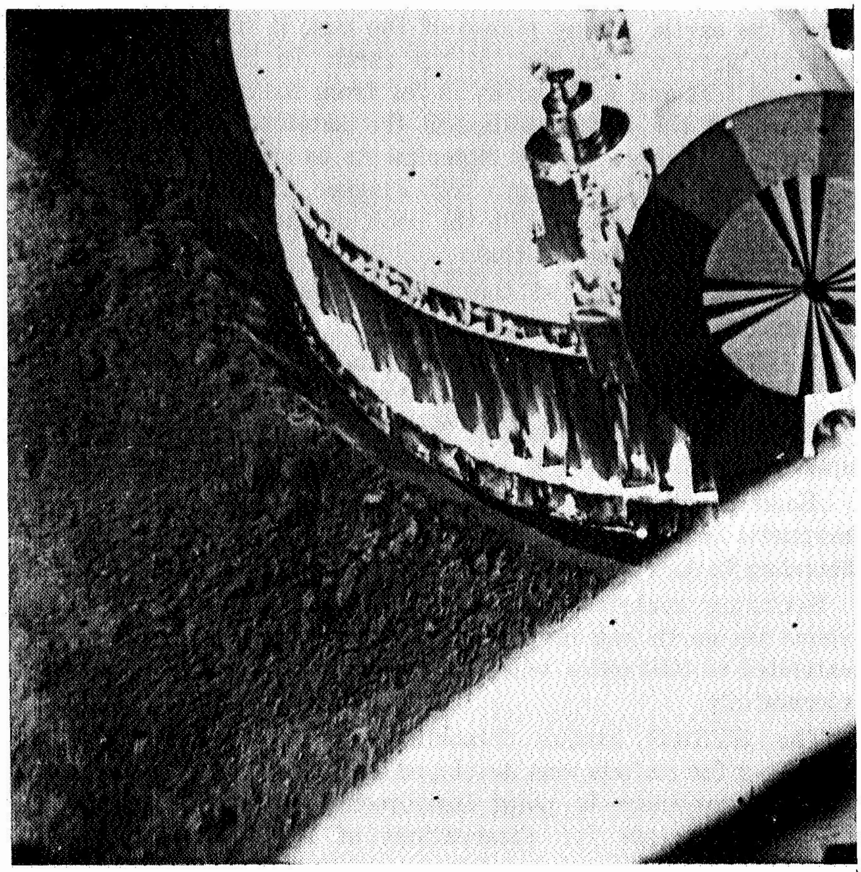


Figure 2–1. Surveyor I closeup showing disturbed lunar material.

Surveyor II was launched September 20, but did not make a soft lunar landing because of a propulsion problem when the midcourse correction was attempted. A Mission Failure Review Board was unable to identify the precise cause of the malfunction, but made recommendations to minimize the probability of its recurrence.

The next two Surveyors to be launched will carry a surface-sampler instrument in addition to the payload flown on the first two. The last three spacecraft in the series will carry an alpha-scatter experiment (instead of a surface sampler) to measure the relative abundance of chemical elements in the lunar surface material.

Lunar Orbiter

The first two in a series of five Lunar Orbiter spacecraft were successfully placed in close-in orbits about the moon during the

last six months of 1966. Each carried a moderate and a high resolution roll film camera, a film processor, a scanning light beam film readout unit, and sensors to measure micrometeoroid flux and radiation in the near lunar environment. The primary objective of the Lunar Orbiter I and II missions was to obtain detailed photographic information on various lunar surface areas along the equatorial belt of the near side of the moon so that their suitability as landing sites for manned Apollo spacecraft and unmanned Surveyor spacecraft could be assessed. Secondary objectives were measurements of the near lunar environment and gathering of precision spacecraft radio tracking data to be used to help determine the nature of the moon's gravitational field. All these objectives were met.

Lunar Orbiter I and II were launched from Cape Kennedy on August 10 and November 6, respectively. Following a 91-hour flight, each spacecraft was placed into an initial 12°-inclination orbit about the moon with a minimum altitude of about 125 miles and a maximum of about 1,150 miles. After several days, the minimum altitude was lowered to under 30 miles for lunar surface photography (Fig. 2–2.)

Lunar Orbiter I photographed 9 potential primary and 7 potential secondary Apollo landing sites, the equatorial region at the east limb of the moon, and portions of the moon's far side. The spacecraft also took the first pictures of the earth from the immediate vicinity of the moon. Lunar Orbiter II photographed 13 other potential primary Apollo landing sites, as well as 17 other sites of interest including oblique views of the Crater Copernicus (fig. 2–3) and the Marius Hills. It also photographed areas on the far side of the moon not covered by the first Lunar Orbiter.

Photographs from the Lunar Orbiter missions were screened and assessed by a team of scientists and engineers from the Langley Research Center, the Manned Spacecraft Center, the U.S. Geological Survey, Army and Air Force mapping agencies, and the Jet Propulsion Laboratory. The screened pictures helped in planning subsequent Lunar Orbiter missions and were being evaluated and studied to select suitable sites for the first Apollo landing mission. Radio tracking data from the spacecraft provided a description of the lunar gravitational field useful in making spacecraft orbital lifetime predictions. The data tended to confirm the current belief that the lunar gravity field does not possess large or unusual variations—a fact of importance in planning manned missions. The micrometeoroid flux in the vicinity of the moon was found to be about the same as that near

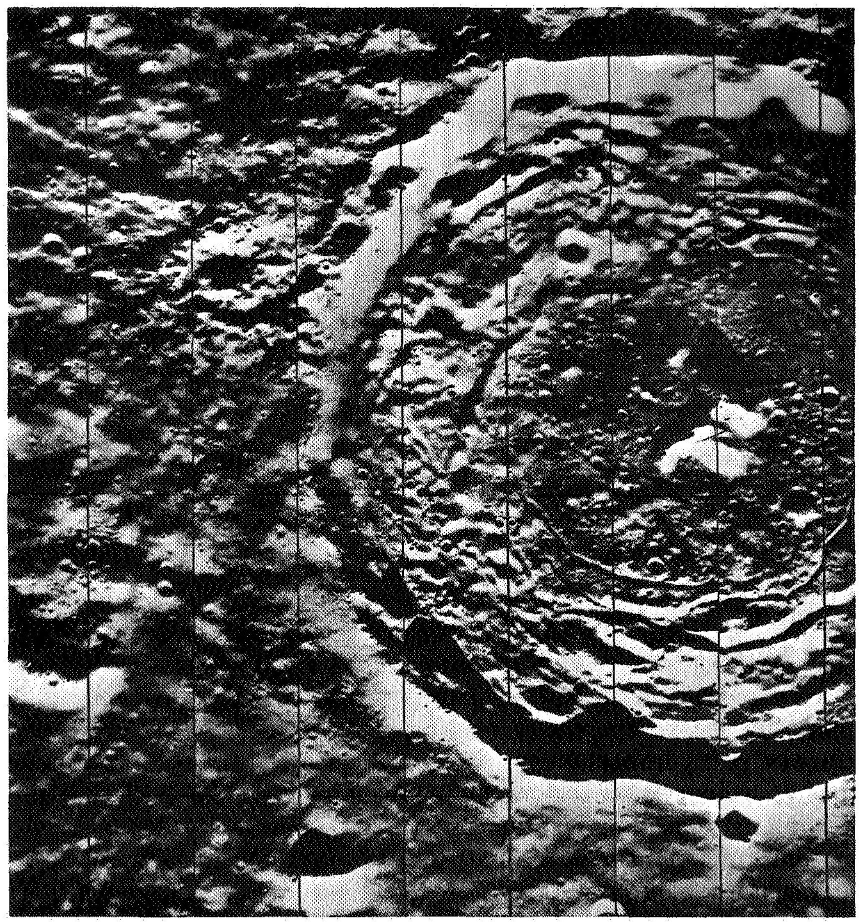


Figure 2-2. Orbiter I photograph of crater on far side of moon.

the earth, and the radiation flux near the moon insignificant except during a major solar flare.

Mariner

A year-and-a-half after returning the first closeup photographs of Mars, Mariner IV had flown more than 1 billion miles and was still transmitting useful scientific data. Its scientific instruments detected a severe solar storm which lasted a week and reached a peak on September 3–4. The solar flare was so intense that it caused a modest reduction in the total power output of Mariner's solar panels, but since the spacecraft was designed for such an occurrence, its performance was not jeopardized.

To prepare for the launching of a Mariner spacecraft to Venus in June 1967, the launch vehicle, spacecraft, tracking and data acquisition systems, and flight operations systems were being

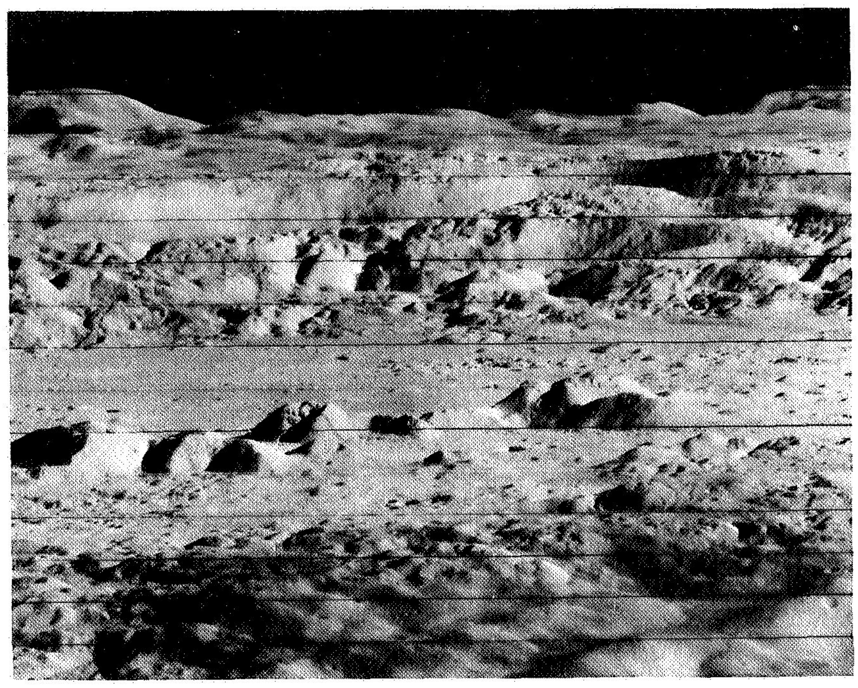


Figure 2–3. The Crater Copernicus as seen by Lunar Orbiter II.

developed and tested. Development test models of the spacecraft were assembled and preliminary system tests conducted satisfactorily; work on the flight spacecraft progressed on schedule. Ground support equipment tests were planned to assure readiness of all support facilities, and operational computation programs were written.

This Mariner, scheduled to pass within 2000 miles of the planet's surface, will obtain data on the origin and nature of Venus and its environment and will complement and extend information derived from the Venus flyby of Mariner II in 1962. NASA also prepared to launch two Mariner spacecraft to flyby Mars during 1969. Both will be of a modified Mariner IV design and use the Atlas-Centaur launch vehicle.

Since selection, in May, of the scientific experiments to be carried by the spacecraft, all major project activities were directed toward selecting spacecraft subsystem contractors, completing spacecraft system design, and establishing a mission profile. Most of the modifications of the spacecraft's design were necessary due to the increased payload over that flown on Mariner IV. Although the detailed design is incomplete, the weight of the instruments and their associated support equipment, such as the scan platform and data handling equipment, is estimated at about 200

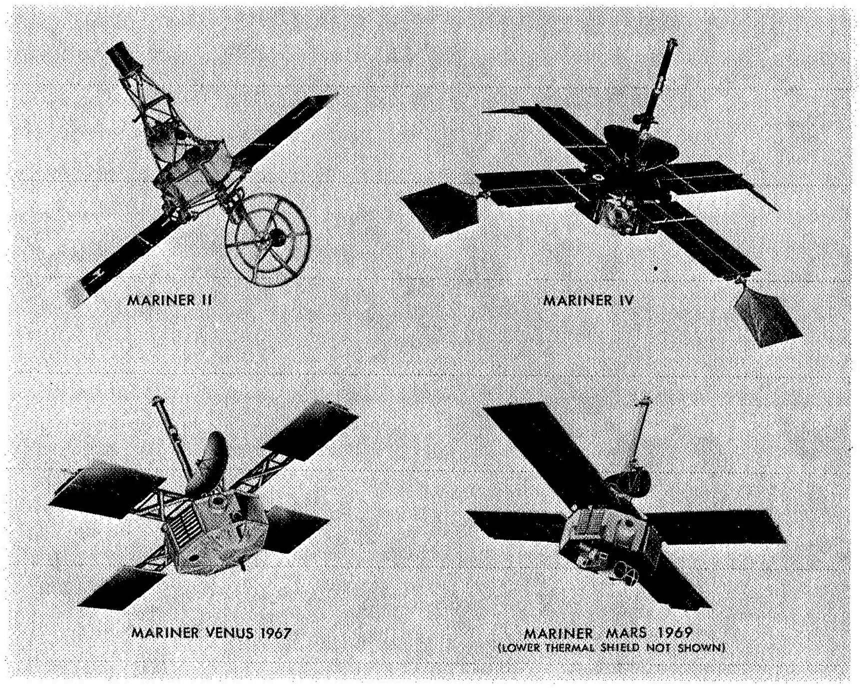


Figure 2–4. The Mariner spacecraft family.

pounds. (Mariner IV's scientific payload was approximately 88 pounds.) To stay within weight limitations the power, data automation and storage, radio, and scan platform subsystems were being redesigned by the project and subsystem contractors.

In addition, a study was underway to determine and establish the mission profile. Although still incomplete, it embraced: a direct ascent launch to inject the spacecraft into a Mars trajectory without using an intervening earth-parking orbit; a Mars transfer trajectory in which the spacecraft traverses an angle of less than 180° about the sun before encountering the planet; a closest approach to flyby the planet at a distance of 1860 miles; and a specific aiming zone for the spacecraft. Scientists also agreed on the details of the encounter sequence and the coverage for each experiment carried by the spacecraft. The launch vehicle, tracking and data acquisition, mission operations, and other related phases of the project progressed satisfactorily.

These flights to Mars should not only provide much more information on the Martian atmosphere and surface but contribute to hardware design and planning for follow-on missions to Mars by Mariner in 1971 and Voyager in 1973.

Voyager

Voyager spacecraft would be used to obtain information on the origin of the solar system, to detect any extraterrestrial life, and to add to bioscientists' understanding of life on earth. The first Voyager flights to Mars were planned for 1973, when the planet is closest to the earth. The spacecraft would orbit the planet and soft land a capsule on its surface. Voyager was designed so that many of its systems such as the spacecraft can be used with a minimum of modification to explore other planets.

Completed capsule design studies resulted in a decision to incorporate an active retropropulsion subsystem into the Voyager capsule. Mission design studies indicated that mission objectives can be met if a Voyager is launched in 1973 and again in 1975, when Mars is nearest to the earth, using a single Saturn V for each launch. Advanced development of the spacecraft, capsule, launch vehicle shroud, and in other areas proceeded on schedule.

ADVANCED PROGRAMS AND TECHNOLOGY

Lunar and Planetary Studies

Lunar and planetary studies, which are needed to determine the feasibility of missions to the moon and to planets, as well as to various asteroids and comets, included one which defined a conceptual design for a spacecraft to pass by Venus and Mercury in 1973. The flyby bus will make indirect measurements of the atmosphere of Venus, and the entry probe direct measurements and high resolution pictures of Mercury's surface after obtaining a gravity assist from Venus. The study also indicated that this mission could be accomplished in 1973 by extending the design of the Mariner spacecraft for the 1969 Mars flyby through the use of an Atlas-Centaur launch vehicle.

Another recent study showed that it may be feasible for an entry probe to reach beneath the cloud layer of Jupiter's atmosphere and relay vital information unobtainable from flyby or orbiter missions. If the probe should enter at a low angle and in the direction of the planet's rotation, it should be able to withstand the aerodynamic heating developed at the high velocities associated with this large planet.

Studies leading to advances in spacecraft technology make it possible to accomplish more and more with smaller launch vehicles such as the Atlas-Centaur. For example, an Atlas-Centaur should be able to place 100 pounds of scientific instruments aboard

a modified Mariner spacecraft into a 24-hour orbit about Mars; the craft could then transmit data at the rate of 100 good resolution TV pictures (or their equivalent) daily for as long as 90 days.

A review of lunar science by the National Academy of Sciences indicated the need for multiple reconnaissance-type landing missions using manned craft and unmanned probes.

A preliminary study was conducted to determine the feasibility and system requirements for an unmanned mission to Mars in the late 1970s, using a Saturn V launch vehicle, to bring back a one- to ten-pound sample of the planet's surface. Also, a study was made of applying Lunar Orbiter subsystems to orbiter missions for Mars and Venus in the early 1970s. Results showed that the performance and reliability of certain Lunar Orbiter critical subsystems might be extended so that an Atlas-Centaur launch vehicle could carry out such a planetary orbiter mission.

Advanced Technical Development and Sterilization Program

This program anticipates the hardware needs of future lunar and planetary missions, and initiates development efforts to provide the improved technology for designers of advanced systems. Almost 80 development tasks, covering all phases of spacecraft system development, were being conducted. Progress continued to be made in life-testing the basic "building blocks" of the spacecraft—piece parts and polymeric products (such as rubber, plastics, and adhesives) which will be incorporated into the design of a sterilizable planetary-landing capsule.

A 60-pound solid propellant rocket motor capable of operating after being sterilized by 6 cycles of heat was being developed. It survived 3 heat cycles, but the propellant bulged after the fourth. Considerable progress was also made in developing the optical approach guidance system which will be tested aboard the Mariner spacecraft scheduled to flyby Mars in 1969. The configuration of the approach guidance system was being determined, its interface with the spacecraft resolved, and fabrication of prototype hardware scheduled to begin.

Systems studies of the problems of assembling a sterilizable spacecraft resulted in the development of a new concept called "sterile assembly and test," which would allow last minute repairs on a planetary spacecraft without disturbing its sterile condition. Improved methods were being developed to screen electronic piece parts used in spacecraft assemblies, leading to an approved parts list for the design and fabrication of long-life advanced planetary spacecraft.

BIOSCIENCE PROGRAMS

Biosatellites

Biosatellite I—the first in NASA's series of recoverable biological satellites to determine the effects of the space environment on various life processes—was launched from Cape Kennedy on December 14. The satellite was injected into orbit with an initial perigee of 159 miles and an apogee of 178 miles. However, it could not be recovered on December 17 as planned because the retro-rocket failed to fire.

The 13 experiments carried on the Biosatellite were designed to study the effects of weightlessness on certain organisms and the effects of weightlessness combined with an on-board radiation source. Basic mechanisms to be studied by the non-irradiated experiments were cell division, the growth in cells of a developing embryo, the effects on the basic structure of protoplasm, effects on enzymes, and the orientation of leaves, roots, and shoots of various plants to gravity. Upon recovery all biological material was to be examined for growth, changes in shape, changes in structure of tissue and cells, and for biochemical changes. The experiments had identical control versions on the ground which were subjected to conditions close to those of the flight experiments, except for weightlessness. The radiation experiments also had nonirradiated replicas aboard the spacecraft that functioned as a control to enable the experimenter to determine the effects of weightlessness only.

Design changes to enhance the likelihood of a successful 3-day mission for Biosatellite B were identified and were being made and tested by the contractor. The satellite (fig. 2–5) was scheduled to be launched in August 1967. In other related work, the spacecraft development model for a 30-day flight was fabricated, and thermal balance, vibration, and functional tests were being conducted. Systems development tests of the primate equipment were being carried on at the University of California (Los Angeles). Most of the work on the 21-day satellite was postponed in order to concentrate on the 3-day and 30-day missions. Some equipment common to the design of the 30- and 21-day spacecraft, such as the fuel cell and cryogenic gas tanks, was fabricated and tested.

Exobiology

A new method was developed for determining whether carbon compounds (such as oils, asphalts, and ancient sediments) were produced by living organisms or by nonliving means. In this method, the gas chromatograph and the new double-focusing

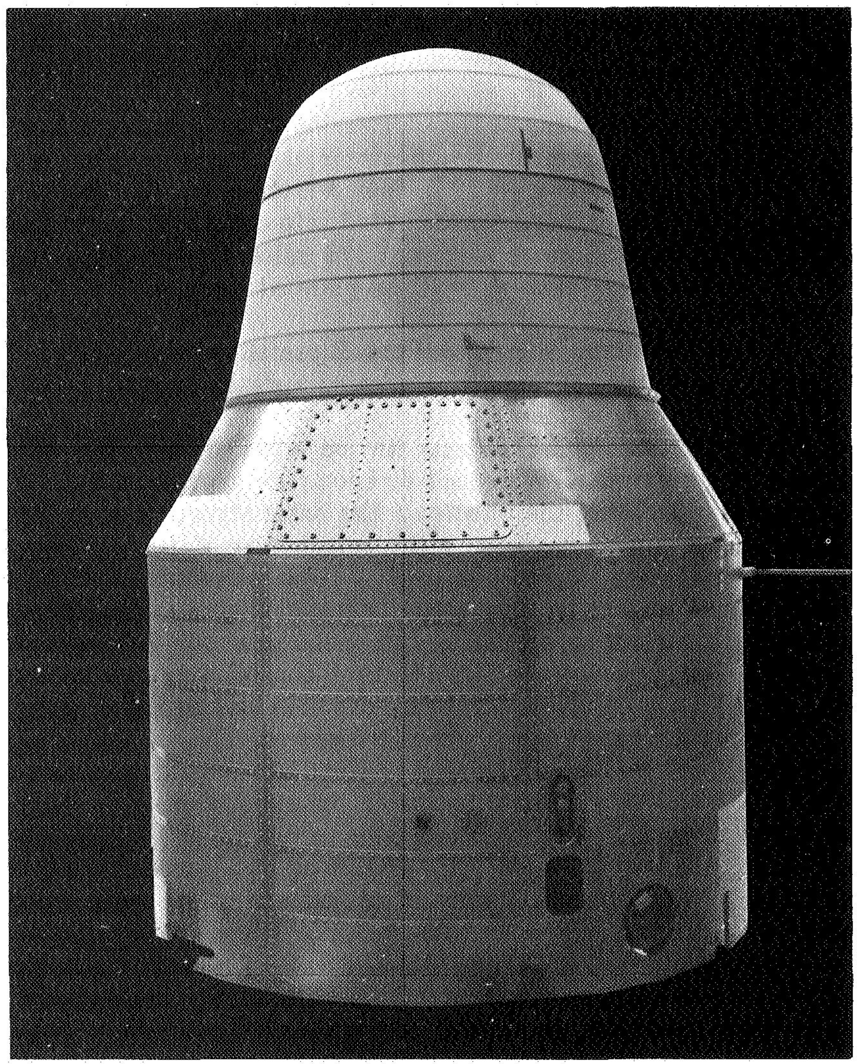


Figure 2–5. Biosatellite B checkout.

high resolution mass spectrometer are used to distinguish between even numbered carbon compounds produced by living organisms only and carbon compounds containing both odd and even numbered carbon molecules produced by nonliving material. Experiments at the Ames Research Center indicate that this method may be used to determine if extraterrestrial matter is biological in origin or in distinguishing living from nonliving material.

A miniaturized, tandemly-operated prototype instrument weighing only 10 to 15 pounds combines gas chromatography and

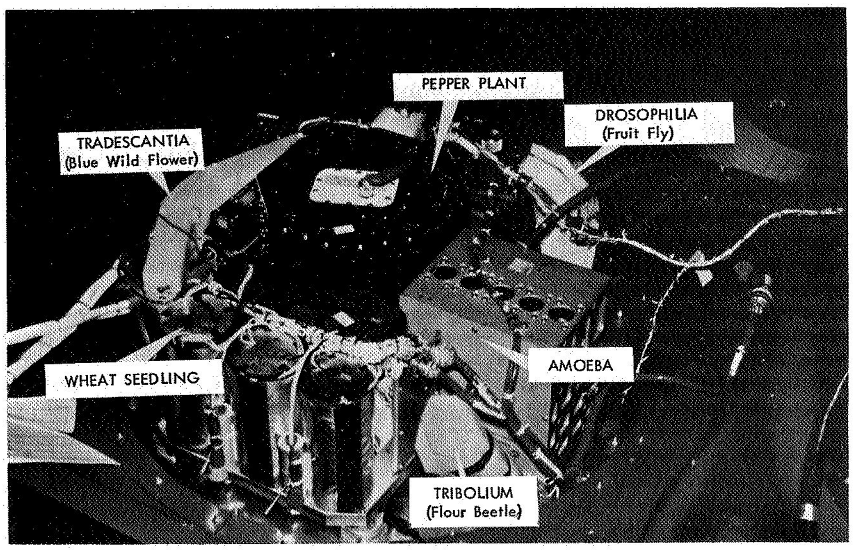


Figure 2–6. Biosatellite experiments for 3-day flight.

double-focusing mass spectrometry and can be used to detect, identify, and characterize life-related chemicals in quantities of less than one microgram (a millionth of a gram). Another advanced instrument is a miniature automated recording microspectrophotometer able to obtain spectral data in seconds. Useful in oceanic, astronomical, and space flight research, this instrument can detect changes in single red blood cells of importance in identifying disease states. It can also follow certain processes in the retina of the eye and possibly lead to a better understanding of color vision.

Several advanced techniques for detecting extraterrestrial life were under study. One refined method based on the uptake of phosphorus by bacteria proved to be sensitive enough to detect several hundred bacteria per milliliter in less than five hours. Another method used an advanced type of chromatograph to isolate and identify certain hydrocarbons in ancient sediments from Michigan and Canada. The distribution of hydrocarbons in the Canadian samples was found to be the same as in samples of biological origin. Carbon 17-saturated hydrocarbons were found in the Michigan sediment.

Many investigators in a number of institutions were devising techniques, establishing procedures, and developing analytical methods for examining samples of the moon from future Apollo missions. A central lunar receiving laboratory was being completed at the Manned Spacecraft Center where returning astronauts will be quarantined and expedited preliminary examinations

of lunar samples will be made before they are distributed to investigators.

Jupiter's "primitive" atmospher (one containing methane, ammonia, and water) was simulated in the laboratory. Electrical discharges applied to this atmosphere produced colored molecules which appeared similar to the colored regions, such as the red spot on the planet. Ammonium cyanide (which is produced from methane and ammonia) in the presence of ammonia may produce the red chromophore.

Exobiologists, who examined recent data relevant to planetary life, reported new absorption bands in the near-infrared in the atmosphere of Mars, tentatively identified in part as due to gases. No such evidence was found for Mercury's atmosphere; however, marginal evidence for Venus provided a rough estimate of 5 percent concentration of hexagonal water-ice crystals in the planet's cloud.

Voyager Biological Laboratory

An integrated package of life detection experiments, the Automated Biological Laboratory was renamed the Voyager Biological Laboratory (VBL) upon becoming a subsystem of NASA's Voyager program; the concept was unchanged.

A feasibility study of a possible VBL to detect life on Mars was successfully completed. Responsibility for studying and developing the Voyager Biological Laboratory was assigned to the Jet Propulsion Laboratory, with Mars and Venus under consideration as possible planetary missions. Thirty-five experiments were being studied for possible integration into the VBL. Each experiment was recommended by scientific advisory groups after carefully considering the need for the experiment to provide the maximum data on any extraterrestrial life detected without duplicating the performance of other experiments.

In addition to being able to reprogram its analyses, repeat its experiments, and perform computations on the data it obtains, the VBL system will be designed to select and reduce data, transmit the information to earth, and receive commands from earth to reprogram its experiments or reconfirm results. Working laboratory models of several of the basic experiments were under development, although the VBL is still in the study phase.

Planetary Quarantine

NASA's planetary quarantine program must delay as much as possible the transfer of life between the earth and the planets, and reduce this transfer of contamination to its lowest possible level between the earth and the moon. The only way that absolute

quarantine can be assured is by not flying spacecraft between these celestial bodies, but the transfer of life can be reduced to a level considered to be acceptable without excessive damage to spacecraft reliability. Unlike surgical instruments, complex and sensitive flight devices cannot be sterilized with steam heat. For this reason research on using dry heat at lower, previously unexplored temperatures for surface and internal sterilization was being carried on.

Since new methods can be used to sterilize only relatively clean spacecraft parts, techniques for biologically clean handling of products were developed. The latter are being used in medicine and in industry, particularly in drug manufacturing. Also, new knowledge was acquired on accelerating the natural death of organisms by controlling humidity and temperature within normal limits. Biologically clean assembly and the death of many of the remaining organisms permit lunar spacecraft to be prepared without special heating and with very little biological contamination at launch.

Biologically clean assembly techniques reduced by 99 percent the viable contamination on surfaces and interfaces of the Anchored Interplanetary Monitoring Probe "D" (launched in July). Ninety percent of the contamination was eliminated from Surveyor II, launched in September, by dry cleaning the spacecraft with small vacuum probes and soft brushes to remove dust particles accumulated during assembly and test operations at the manufacturing plant and at the launch site. Extremely rigid personnel and materiel controls in conventional air handling facilities during the checkout phase of the August and November Lunar Orbiter launches, coupled with a modified laminar downflow clean air handling system in the final checkout facility prior to enshrouding, reduced and controlled the microorganisms on surfaces of these orbiters to exceedingly low concentrations.

More detailed research on actual dry heat sterilization of planetary spacecraft lowered requirements from 135° C for 24 hours to less than 24 hours at 125° C, and also reduced the total cost of spacecraft sterilization. Despite the lowered heat requirements, some spacecraft parts will be destroyed at these temperatures. A new technology being developed will permit these parts to be sterilized separately and inserted into the sterilized main body of the spacecraft without destroying the sterility of either.

Accidental contamination of a planet by the nonsterile portion of the spacecraft was being analyzed and corrective measures being devised. Trajectory studies of the spacecraft and of small particles ejected from it were completed, and methods of preventing contamination of the landing hardware during separation

from the vehicle were under study. All these measures were part of an effort to carry out international agreements to prevent the contamination of space and celestial bodies.

Environmental Biology

Space Flight and Space Environmental Factors.—Experiments were conducted to determine if chromosome breaks during space flight were due to the combined or individual effects of radiation and vibration. Experimenters who used mammalian cells in culture found that the joint action of vibration and radiation did not affect cell survival at 100 or 1000 cycles a second even at quite high sound intensities. At ultrasonic frequency (about 10^6 cycles), a very weak ultrasound combined with radiation to affect cell survival and chromosome breaks. Ultrasound alone at this intensity showed no demonstratable effects.

Female beagle dogs—exposed to whole body radiation and immediately afterwards subjected to a simulated altitude of 18,000 feet for almost two months—experienced changes in blood chemistry, blood counts, bone marrow, and total body volumes. The parasitic wasp, *Habrobracon,* was used to determine the combined effects on egg production of radiation from a cobalt-60 gamma source and a vibration of 160 cycles a second for one hour. Ionizing radiation in combination with vibration resulted in more pronounced effects than the same radiation dose administered separately.

Hibernation as Protection Against Radiation.—Bioscientists have found that hibernation can protect an animal against radiation. In experiments with ground squirrels, fewer died when exposed to whole body radiation during their hibernation. Many of the animals subjected to doses of radiation lived for several months, gained weight, and behaved just like nonirradiated ones.

Magnetism.—Wheat seedlings grown in a zero magnetic field were found to be larger and more robust than others grown in a normal environment. High magnetic fields afforded flour beetles a considerable amount of protection against deformations caused by heat. When the insects (one of the organisms flown on the first Biosatellite) were heated to a few degrees above human body temperature, they failed to develop into adults. Kept at the same temperature but in high magnetic fields, 80 percent of the insects developed into normal adults.

Gaseous Environments.—In a series of tests, human subjects breathed either air or 79 percent helium—21 percent oxygen while the body was exposed to air or to a 79 percent helium—21 percent oxygen atmosphere at 85° F. The results indicated that the

major, if not the sole effect of helium, was heat loss from the skin (at least at 85° F). Skin temperatures were lower in air contact than when helium-oxygen was in contact with the body surface, regardless of whether air or helium-oxygen was breathed. There was no difference in oxygen uptake.

When rats were exposed to a high oxygen-low pressure environment (100 percent oxygen at 5 pounds per square inch absolute), their body weights were somewhat greater after 12 weeks of continuous exposure than those of control animals, and the carbohydrate content of tissues and carcasses was also greater. In addition, serum and tissue cholesterol concentrations increased. These concentrations in the liver and kidneys returned to normal after the 12 weeks of exposure, but the heart cholesterol concentrations were still high. These data suggest the possibility of atherosclerosis (a lesion of large- and medium-sized arteries) in susceptible animals and in man.

Extreme Environments.—In general, life requires enough water, warmth, atmosphere, nutrient, and energy sources, but a large number of organisms are able to live under extreme environmental conditions from the ocean depths to the alpine peaks. For example, the microorganism *Chromatium* must have high concentrations of salt for life. It can survive and grow inside a mirabilite crystal (a mineral deposit from saline lakes) completely sealed away from external water, and its growth is not affected after being exposed to temperatures ranging from 110° C to −15° C. Damage from cold to boxwood shrubs exposed to 30° F below freezing for 22 hours, was considerably reduced when they were thawed for 12 hours in a nitrogen atmosphere instead of in air.

Cardiovascular Problems.—Scientists who implanted electromagnetic blood flow probes in the aorta of the heart of the pigtailed monkey (*Macaca nemestrina*) obtained data for bioscience space missions. From flow probes functioning for 29 and for over 60 days, they found a daily blood flow pattern with the lowest flow rates during the early morning hours and the peak flow rates in the late afternoon. Extending these studies investigators determined that the cardiovascular system of the monkeys reacted to the drugs epinephrine and norepinephrine in the same way that the human cardiovascular system responded.

Bone Mineral Metabolism.—Gemini IV and V astronauts after their flights in June and August 1965 showed significant decreases in bone mineral, which were revealed by bone X-ray densitometry techniques developed in NASA's environmental biology program. At the University of Kentucky, experimenters

were studying bone metabolism to determine some of the reasons for the bone mineral losses. When they used radioactive calcium, bone tissue in immobilized animals showed a 27 percent increase in the active release of calcium, an effect which could be due to a deficiency in dietary ascorbic acid. A more important finding was that the deposition or replacement of the lost calcium was reduced by 37 percent.

Behavioral Biology

Research into the behavioral aspects of space biology has added to bioscientists' knowledge of the total response of organisms to space environmental conditions. The external and internal causes and factors controlling sleep and other rhythms of life forms in approximate 24-hour cycles are of fundamental and applied interest to space biologists. For example, subjects at the Max Planck Institute for Behavioral Physiology were isolated in underground bunkers and subjected to changes in dark and light periods similar to aircraft flights in easterly and westerly direction. When the dark time ("easterly flight") was shortened the test subjects readapted immediately, but it took longer for them to re-adapt after a briefer "westerly flight."

University of Minnesota investigators used computers to analyze circadian rhythm data obtained in France from two adult human subjects who volunteered to spend three to four months in underground caves without known time cues. (Circadian rhythms are regular changes in physiological functions occurring in organisms in about 24-hour cycles.)

The artificial heat and light were turned on each time the test subjects awakened, and turned off after they went to bed. Routine clinical and biological examinations indicated that their stay underground was well tolerated. The elimination of synchronizers (such as alternating light and darkness, and the hourly constraints imposed by society) allowed investigators to study unhampered free-running circadian rhythms in sleep-wakefulness, in pulse rate, and in body temperature. Computer data analysis showed that circadian rhythms were maintained during the entire period of isolation underground and were longer than the precise 24-hour cycles. Since the rhythms of the subjects were not synchronized with local time, there was evidence that these rhythms originate (at least in part) in the subjects themselves rather than in their environment, and that environmental factors are primarily synchronizers.

Studies recently completed at the Massachusetts Institute of Technology to show the significance of environmental stimulation on behavior and physiological functions of immature mammalian

organisms illustrated that severe restriction of early sensory experience in dogs produced striking abnormalities in their behavior at maturity. Other studies, at the University of Southern California, indicated that manipulation of early experience with environmental stimuli (physical and social) resulted in persistent hypertension and associated changes in the endocrine and cardiovascular systems.

At Johns Hopkins University techniques were being developed to investigate the effects of prolonged weightlessness on the nervous control of circulation. One study confirmed that electrocardiographic abnormalities, blood pressure, and heart rate changes induced by brain stimulation could be conditioned. In another project conducted at the University of Kentucky, the role gravity plays in controlling behavior was studied. Monkeys were given access to a lever which controlled the rate of rotation of an automatically-programmed centrifuge. (Fig. 2–7.) When the lever was pressed the amount of artificial gravity was reduced by reducing the rate of rotation. The monkeys were thus able to choose to avoid g-levels above normal earth gravity over periods of many weeks. In-flight experiments will be needed to extend these studies to gravity levels below 1 g.

Biophysics and Molecular Biology

A new computerized technique was developed to measure

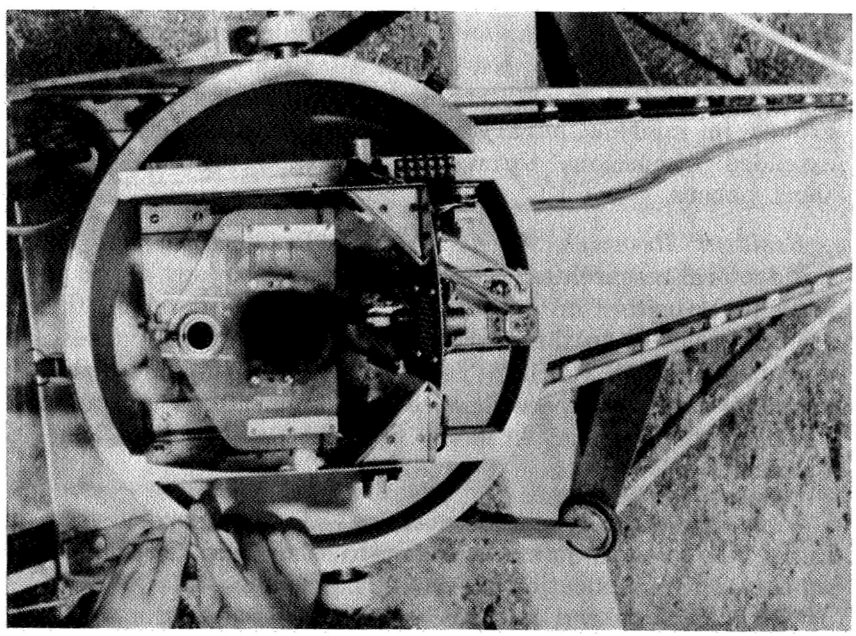


Figure 2–7. Monkey in automatically-programmed centrifuge.

chemical reactions in proteins and nucleic acids within a cell by using light pulses of a few billionths of a second. This method allows scientists to investigate extremely fast biological and biochemical events, to help explain the relationship between structure and function in proteins and nucleic acides (determinants of the genetics of an organism), and to study the structure and interactions of large biological cellular molecules.

Bioscience Communications

Advisory Panels and Special Conferences.—Advisory panels on behavioral biology, environmental biology, and exobiology, established in 1966 under contract with the American Institute of Biological Sciences (*15th Semiannual Report,* p. 62), served effectively in evaluating the scientific merit of research proposals and in advising NASA on special scientific problems. Special conferences were arranged as needed by the Agency's scientists, research contractors, and grantees to present and discuss research and associated problems in space biology.

Scientific Communications Research in Space Biology.—George Washington University's Biological Sciences Communications Project provided an effective link between NASA and scientists in the universities, industry, and in all other Federal agencies helping to support life sciences—especially such programs as spacecraft sterilization.

Interdisciplinary Communications.—Under contract with the Smithsonian Institution, NASA has established a conference program to provide a special technique for managing small informal groups in interdisciplinary discussions. The conferences allow extended discussions through formal presentations of many short papers.

Resident Research Associateships.—Postdoctoral and senior postdoctoral research associateships in space biology afford promising investigators an opportunity for basic research in the life sciences relative to the space program. These resident research associateships at NASA's field centers are supported by the Agency's Office of Space Science and Applications and administered by the National Academy of Sciences—National Research Council.

U.S.—U.S.S.R. Bioscience Review.—A bioscience review being prepared by a joint American-Russian editorial board, was scheduled for publication in 1968. The review—*The Foundations of Space Biology and Medicine*—was discussed in the *15th Semannual Report,* p. 61.)

MANNED SPACE SCIENCE

Gemini Earth-Orbital Experiments

Scientific investigations, which began with two experiments during the flight of Gemini III in March 1965, reached a maximum of nine successful experiments with the Gemini XI mission in September 1966. The Gemini program included 19 individual experiments, some conducted during several flights—for a total of 50 performances. Since most of the experiments were performed during the later Gemini flights, data were still being analyzed by the principal investigators. However, enough of the preliminary results have been determined for this brief summary.

The zodiacal light photography experiment of the University of Minnesota, first flown on Gemini V (August 1965), was conducted again on Gemini X in July 1966. Photographs of this astronomical phenomenon were also obtained from Gemini V and Gemini IX–A (June 1966). The Gemini IX pictures were especially good, showing the zodiacal light and the Milky Way in the bright moonlight. Gemini X photographs gave additional information on the zodiacal light, which is almost impossible to observe and photograph from the ground because of interference from light from cities, airglow, and other faint sources of celestial light.

The frog egg growth experiment of Ames Research Center—partially completed on Gemini VIII (March 1966)—was flown again during Gemini XII in November. Its purpose was to determine the effect of weightlessness on the development of fertilized frog eggs. (Fig. 2–8.) It was completely successful since the eggs returned in the later embryonic stages of development. When some were allowed to continue development, they became live swimming tadpoles which lived for several hours after the flight. A complete study was underway of the partially developed eggs and those which were completely developed, as well as of a control group on the ground. Preliminary indications were that no abnormalities in the developing frog eggs were caused by the flight, but more conclusive results will be forthcoming after complete study.

Experiments on the combined effects of weightlessness and radiation on human white blood cells were conducted during the Gemini III and XI missions. Blood cells flown on Gemini III were subjected to a known quantity of radiation during the flight and a control sample was similarly irradiated on the ground. The results of this experiment seemed to indicate an increase in single breaks in chromosomes (a finding announced by the Rus-

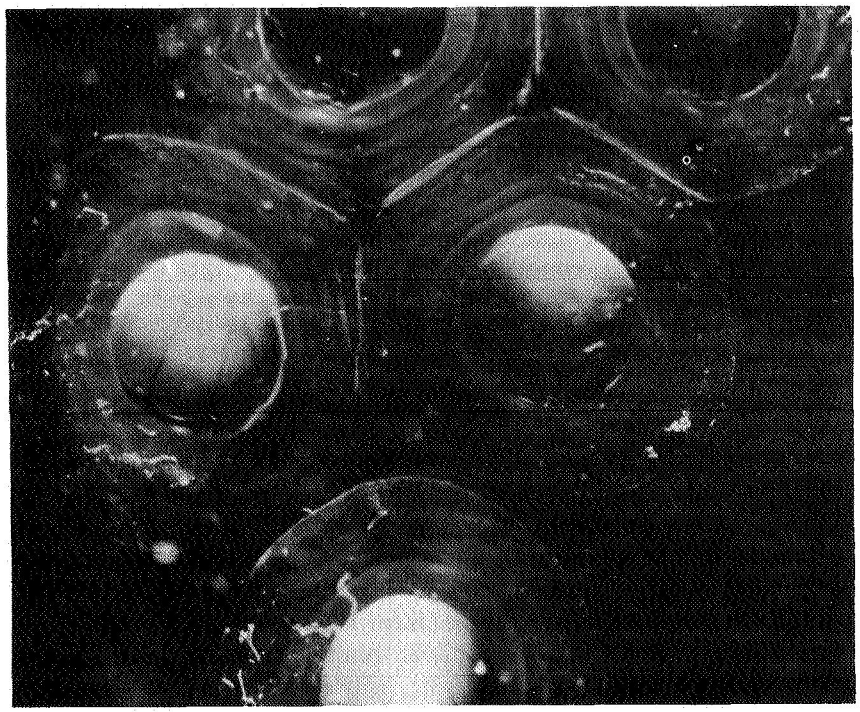


Figure 2–8. Frog eggs with 8 cells after 2.5 hours of weightlessness.

sians also). In a reflight of the experiment on Gemini XI neurospora (bread mold) was flown in addition to the blood cells. Unlike the results from the Gemini III flight, no increase in single breaks in chromosomes in the blood cells was found over those of the ground control samples. Analyses were being carried out on the neurospora, and preliminary results indicated there was no increase in mutation frequency in the flight sample.

The synoptic terrain photography experiment—flown on Gemini IV, V, VI, VII, X, XI, and XII—produced many fine pictures of the earth. The experiment was carried out during other Gemini flights when time permitted and film in the cameras was available. This, and its companion synoptic weather photography experiment, provided about 1900 high-quality color photographs of selected areas of the earth. The pictures were sent to such agencies as the United States Geological Survey, the Navy Oceanographic Office, the state geologic survey offices of Arizona, Texas, and New Mexico, and to various other governments, upon request, where they are being used for geologic, geographic, and oceanographic studies. The agencies and individual scientists also requested selected photographs of areas of

specific interest. When feasible, NASA honors these requests and will continue to honor them on Apollo flights.

The synoptic weather photography experiment obtained high-resolution color photographs of clouds for analysis and comparison with pictures relayed to the ground by weather satellites. It used the same camera equipment and was carried on the same missions as the synoptic terrain photography experiment. The hundreds of useful pictures provided enough overlapping sequences to permit excellent stereo-viewing; cloud formations accompanying the high altitude jet stream were photographed during the Gemini XII flight. Photographs like these should add to scientists' knowledge of cloud movements and formation.

The nuclear emulsion experiment of the Naval Research Laboratory was flown on Gemini XI to perform a qualitative study of heavy primary nuclear particles by examining their tracks in a nuclear emulsion stack. The experimental package containing photographic emulsion for a galactic cosmic ray study was retrieved by Astronaut Gordon at the beginning of his first "walk in space" during this mission. When the emulsions were developed, preliminary microscopic analysis showed that they had received the expected amount of background proton radiation during the flight over a region of the South Atlantic (the South Atlantic anomaly region).

The Agena micrometeorite collection experiment was first placed on that vehicle during the Gemini VIII mission and was to be opened during the extravehicular activity of that flight. Since the mission was terminated early, the collection box with its specially prepared exterior surfaces to record micrometeorite impacts could not be opened. It remained in space for four months and was retrieved by Astronaut Collins during his Gemini space walk. This was the first time that a man had recovered a scientific article from space. An analysis of the exterior surfaces of the box showed good photographs of micrometeorite impacts.

Other Gemini micrometeorite collection packages were opened and brought back from outside Gemini spacecraft during stand-up extravehicular activity. On Gemini IX the experiment package was exposed to space for 16 hours and retrieved; the next one, flown on Gemini X, was lost in space. Another package, on Gemini XII, was exposed for six hours for comparison with the longer exposures of the Gemini XI flight. When this package was retrieved, no impacts were evident from a preliminary examination of a square centimeter of its surface, but examination and analysis continued. "Guest" experimenters with this collection package were groups in three foreign countries as well as

groups in this country. One guest experiment was the microbiological exposure experiment of the New York State Department of Health and the Dudley Observatory. This experiment was designed to test the survivability of terrestrial microorganisms in space and to collect viable microorganisms existing in the vicinity of the spacecraft. Preliminary results indicated that certain organisms can and did survive in the space environment.

The airglow horizon photography experiment was flown on Gemini IX–A, XI, and XII. From Gemini IX–A, 45 excellent pictures were obtained of the stars and were being analyzed. The Gemini XI flight provided 25 pictures, and the Gemini XII missions collected 24 photographs during three night passes. These flights obtained much more new data on airglow than all previously supplied by other methods such as rockets.

The ultraviolet experiment of Dearborn Observatory provided the first stellar ultraviolet spectrograms from a satellite (Gemini X, XI, and XII). The objective of this ultraviolet (UV) stellar photography was to obtain UV spectra of young (hot) stars in short wavelengths—from 2000 to 4000 angstroms. First performed on Gemini X during the astronaut's standup extravehicular activity, a Maurer 70 mm camera (UV lens) with a diffraction grating and prism arrangement was used for time exposures of from 20 to 60 seconds. The experiment was performed while the spacecraft was docked with the Agena. Photographs were obtained of starfields in the Milky Way from Beta Crucis to Gamma Velorum. On the Gemini XII mission a spectrum of the bright star Sirius was obtained in a 20-second exposure.

The Gemini X and XI rendezvous tests with the Agena provided opportunities to investigate the ion wake of an orbiting vehicle in a simplified, direct manner. Three uniquely-shaped retarding potential analyzers were mounted in the docking cone of the Agena to sample the ion and electron densities during the rendezvous maneuvers. On the Gemini XI test realtime telemetry data were used—the first time that such information was available for a scientific experiment—and allowed various spacecraft operations to be observed, including tethering and rotating. Knowledge of these operations was useful during the flight and later in analyzing data. The experiment proved that the spacecraft has an ionized wake and travels in its own cloud of gases.

Bone X-ray densitometry studies of astronauts' bone mineral losses during several Gemini missions used a technique developed by NASA for its Biosatellite and manned flights. Results indicated a greater bone mineral loss from the skeleton during the shorter Gemini flights than in immobilization during complete bed rest. There was decreased loss during the two-week flight

when the astronauts ate high calcium diets and used an exerciser.

Apollo Earth-Orbital Experiments

Much of the hardware for scientific experiments on early Apollo flights has been built and tested extensively to qualify for flights on manned vehicles. As in the Gemini program, experiments on these flights will be on a "noninterference" basis—planned not to interfere with the primary objectives of developing spacecraft and operational techniques needed for manned lunar landings.

New experiments in the manned flight experiments program are constantly being received, reviewed, and selected for flight. Six experiments were approved for Apollo earth-orbital flights and several others were considered by NASA's Space Science Steering Committee but await assignments to specific flights. They may be assigned to later Saturn-Apollo applications missions. The six approved experiments were: synoptic terrain photography, synoptic weather photography, dim light photography, sodium vapor cloud experiment, ultraviolet stellar astronomy, and ultraviolet X-ray solar photography.

The synoptic terrain photography is a continuation of experiments conducted during Gemini flights. All requests from scientists and various agencies for photographic coverage of specific areas of interest are coordinated and a mission plan devised for the experiment consistent with the overall flight mission plan and with the areas best photographed from that particular flight. Good-quality, high-resolution color photographs of cloud formations, storm areas, and other weather phenomena are obtained for meteorologists to use in studying weather movements and to aid in understanding black and white photographs transmitted by meteorological satellites.

The dim light photography experiment provides and analyzes for astronomers, physicists, and meteorologists, photographic observations of the twilight arc and then compares these observations with the results of theoretical-numerical model studies. This experiment of Goddard Space Flight Center and the National Center for Atmospheric Research is an outgrowth and extension of work being performed by the Laboratory of Atmospheric Sciences at the National Center for Atmospheric Research (Boulder, Colorado).

Two additional experiments to be flown in the Apollo program will have direct applications to later flights of astronomical telescopes and observatories. One is the ultraviolet stellar photography experiment, an improved version of a highly successful Gemini experiment. Its major purposes are to obtain a large

number of spectra of early-type stars, direct photographs of a large number of Milky Way star fields, and to gain experience in making photographic astronomical observations from manned space vehicles.

The other astronomy experiment is photography of the extreme ultraviolet and soft X-ray solar spectrum. Data obtained should provide at least ten times more information on the solar spectrum in wavelengths of from 1000 to 10 angstroms than provided by photographic spectrographs in present rockets or by photoelectric scanning-type spectrographs in automated satellites.

Apollo Lunar-Surface Experiments

In the Apollo program's manned lunar landing phase, the scientific experiment with the highest priority of the early landings is collecting and returning to earth samples of lunar materials, some of which will be made available to leading scientists and institutions throughout the world for study and analysis. During each mission, astronauts will collect about 50 pounds of assorted easily obtainable samples of any surface material at the lunar landing site. No analysis of the samples, other than a cursory examination, will be attempted on the moon since time and instrumentation will be limited.

The second and third scientific goals of these early manned lunar landings are to place the Apollo Lunar Surface Experiments Package on the moon, and for astronauts to perform a detailed geological and biological survey by sampling and photographing representative and unusual rocks or formations. Samples collected during the survey will be returned to earth for analysis.

A lunar receiving laboratory was under construction at the Manned Spacecraft Center to carry out preliminary examinations and assure biological quarantine of the returned lunar samples. This laboratory, to be finished in 1967, could perform all of the necessary initial examinations and the quarantine before the samples are distributed to scientists at individual laboratories and universities taking part in the lunar sample analysis program.

Apollo Lunar Surface Experiments Package.—The Apollo Lunar Surface Experiments Package (ALSEP) will obtain measurements of the moon's physical properties. This data should lead to a better understanding of the role played by the moon in the origin and history of the earth; the composition and structure of the moon; processes which affected or modified its surface and its interior; its external environment; and the history or evolutionary sequence which resulted in its present configuration.

The objectives of the lunar surface science program—to be achieved by the astronauts and by earth-bound data analysis—are visual observations of the lunar surface; the collection and photography of lunar surface and subsurface samples; and the analysis of data telemetered to earth from the ALSEP experiments on the moon's surface.

The eight ALSEP experiments will telemeter scientific information to the earth for at least a year. Five or six of the eight will be carried on each Apollo lunar mission. The experiments were selected and the instruments were designed to measure physical and environmental data on the lunar surface; the interior of the moon to its core; and the environment surrounding the moon.

The ALSEP will be powered by a SNAP–27 radioisotope thermoelectric generator. The Atomic Energy Commission is funding and managing the development of this generator.

The ALSEP has moved from the design to the equipment phase and tests of the engineering model were in progress. Results indicated that the experiments, the central station, and SNAP–27 were performing according to or better than expected.

Apollo Telescope Mount

An Apollo Telescope Mount (ATM) was approved for use by future astronauts in manned flights. The crew of Gemini IX (in September) used the ATM in photography which resulted in the discovery of absorption lines of iron and magnesium in the ultraviolet light from the constellations Orion, Scorpius, and Carina. Previously these absorption lines had been seen in the solar spectrum only.

LIGHT AND MEDIUM LAUNCH VEHICLES

Scout, Delta, Agena, and Atlas-Centaur vehicles were used by NASA to launch spacecraft in its space science and applications programs.

Scout

Scout vehicles were successfully flown on June 10, August 4, August 17 and October 28, boosting Scout's launch record to 22 consecutive successes. The Scout vehicle continued to be improved as development of a fifth-stage velocity package was started. In this development a fifth-stage motor will be incorporated into a standard Scout stage (as previously incorporated into several Scout payloads) to provide increased performance for solar probes and earth orbits.

Delta

Delta launch vehicles succeeded in the five missions undertaken. Explorer XXXIII was launched on July 1, into the highest earth orbit ever achieved by a satellite. On August 17, another Delta successfully launched Pioneer VII into its required solar orbit. ESSA–III was successfully launched into a polar orbit by a Delta vehicle on October 2—the first Delta to be launched from the Western Test Range (Point Arguello, California). Delta also launched the first spacecraft of Comsat's Intelsat–II program on October 26. Although Delta placed the spacecraft into a nearly perfect transfer orbit, a malfunction in the spacecraft's apogee motor firing resulted in an orbit which limited its performance. Finally, NASA's first Biosatellite was launched on the first two-stage Delta vehicle on December 14.

During 1966, eight Delta vehicles were successfully launched in as many attempts and the overall record for this launch vehicle reached 39 successes in 43 attempts.

Agena

In each of five attempts Agena vehicles were successful.

OGO–III.—When the third Orbiting Geophysical Observatory (OGO–III) was launched from Cape Kennedy on June 6, the Atlas-Agena vehicle operated flawlessly, placing the spacecraft into its desired orbit. All vehicle test objectives were achieved.

PAGEOS I.—The passive geodetic satellite PAGEOS–I was launched by a thrust-augmented Thor-Agena on June 23, almost exactly into its predicted orbit and vehicle test objectives were realized.

Lunar Orbiter I and II.—These two lunar photographic missions were successfully carried out by Atlas-Agena launch vehicles in August and November, respectively.

ATS–I.—The first applications satellite, ATS–I, was successfully placed into a synchronous transfer orbit by an Atlas-Agena vehicle in December—the first attempt by this vehicle for a synchronous mission.

Launch Vehicle Status.—Launch vehicle preparations for missions scheduled for 1967 continued concurrently with these 1966 launchings. The scheduled missions included two Lunar Orbiters, a Mariner Mars flyby, a Polar Orbiting Geophysical Observatory, and two Applications Technology Satellites. Vehicle work was currently on schedule to support the launch dates planned for these missions. Efforts also continued on developing the Improved Atlas for Centaur and Agena missions. This improvement will

enable Atlas-Centaur and Atlas-Agena to carry payloads weighing 300 pounds more.

To cope with increasing performance requirements, particularly of the Nimbus meteorological missions, NASA has elected to use the Long Tank Thor (or Thorad) developed by the Air Force for its Agena missions. This improvement allows Nimbus (already integrated with the Agena) to remain on that vehicle while gaining increased performance.

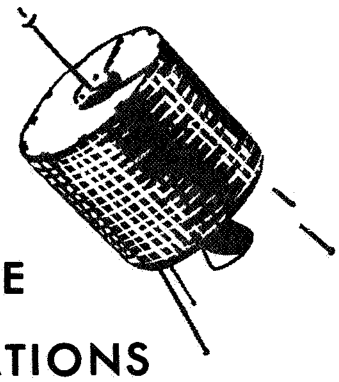
Facilities.—Modifications were planned for the Agena launch complexes at both test ranges to make them compatible with the improved boosters of the Agena program. At the Western Test Range, Space Launch Complex 2–East will be modified for compatibility with the Thorad booster. (This booster will also be used by Delta which shares the complex with Agena.) At the Eastern Test Range, modifications were begun for a changeover to the Improved Atlas booster.

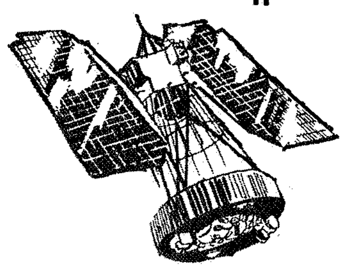
Atlas-Centaur

The final development flight of Atlas-Centaur—the first U.S. launch vehicle to use liquid hydrogen fuel—was on October 26, the culmination of eight years of development effort. The second operational flight was conducted in September when Centaur AC–7 boosted Surveyor II into the desired lunar transfer trajectory.

Atlas-Centaur's role in supporting NASA missions was expanded when it was assigned to be the launch vehicle for the remaining Orbiting Astronomical Observatory flights and for the Applications Technology Satellites D and E missions. It had already been assigned as launch vehicle for the remaining Surveyor mission, Applications Technology Satellites F and G, and the Mariner Mars flyby in 1969.

3 SATELLITE APPLICATIONS





In this area of wide-ranging activity, considerable progress was recorded. ESSA III, launched by NASA in October, joined the operational meteorological satellite system. Nimbus II (orbited in May) provided the most comprehensive data thus far obtained on the structure of the global atmosphere. Also in October, another commercial communications satellite, linking Hawaii and the U.S. mainland, was orbited for Comsat. The first Applications Technology Satellite was launched in December; it carried several advanced meteorological and communications experiments and was the largest spacecraft ever placed in a geostationary orbit by NASA. Two earlier-launched geodetic satellites supplied daily tracking service to ground stations around the world. And the Earth Resources Survey Program used photographs taken by Gemini astronauts, and TIROS and Nimbus TV pictures to locate geologic features, chart polar sea ice, and update maps.

METEOROLOGY

TIROS

NASA launched ESSA III on October 2 for the Environmental Science Services Administration to assure continuing operation of the national operational meteorological satellite system inaugurated in February. (One of ESSA I's cameras failed in July,

resulting in the loss of complete global coverage by this satellite. However, Nimbus II (p. 104) and TIROS IX filled the gap in coverage, supplying the necessary additional operational data from late July until early October.) ESSA III was the first operational satellite to carry the Advanced Vidicon Camera System (AVCS) developed for and successfully flight tested on Nimbus I and II. The AVCS cameras continued to provide pictures of excellent quality. ESSA uses these global photographs routinely in daily weather analysis and forecasting and prepares cloud analysis charts for dissemination to worldwide weather services. ESSA III also carries a low resolution infrared radiation monitor to measure the short-wave radiation reflected by the earth and its atmosphere and the long-wave radiation emitted by the earth. These measurements are used to chart the global heat balance.

ESSA II, launched in February, still furnished direct readout pictures to over 162 Automatic Picture Transmission (APT) ground stations around the world, including 38 stations operated by foreign governments.

The design study for the TIROS M research and development spacecraft was completed, and the hardware contract was being negotiated. TIROS M will carry the AVCS, APT, and the High Resolution Infrared Radiometer (HRIR) with direct readout for local and global cloud observations during the day, and at night through its secondary sensors—a flat plate radiometer and a solar proton monitor. It is the prototype for the next generation of ESSA spacecraft (Improved TOS) planned to be incorporated into the operational meteorological system by about 1970. In the TOS improvement program, a camera was under development with increased resolution and an on-board gridding subsystem for APT to increase the accuracy and eliminate the manual gridding now required at each APT ground station.

The TIROS VII, VIII, IX, and X cameras continued to provide meteorologically usable pictures. TIROS VII completed over 3½ years of successful operation, sending back over 111,000 of these cloud pictures.

Nimbus

Nimbus II was orbited on May 15 (*15th Semiannual Report*, p. 67). The three cameras of its Advanced Vidicon Camera System, operating simultaneously, provided daily more than 1300 daytime TV pictures of the earth and its cloud cover with a resolution of about ½ mile. Although a tape recorder associated with the camera system failed after 3½ months (on August 31), the cameras supplied over 112,000 usable pictures. The Auto-

matic Picture Transmission camera system—photographing an area of 3½ million square miles—transmitted pictures directly to local APT ground stations when the satellite was within radio reception range (about 2140 miles). Over 162 ground stations, including 38 in foreign countries, received these pictures. The Data Code Experiment was added to Nimbus II to provide world-wide users with automatic picture times and a technique for updating ephemeris data for antenna orientation and picture gridding—data very useful to APT stations without access to orbital information.

The High Resolution Infrared Radiometer on the spacecraft supplied the major Nimbus ground stations at Fairbanks, Alaska, and Rosman, North Carolina with stored global cloud data for transmission to Goddard Space Flight Center. A spacecraft innovation was the addition of HRIR data to the APT system, permitting direct readout of nighttime cloud cover by APT ground stations and doubling the frequency of data at these stations. By November, 35 stations were modified for direct readout, including 12 in foreign countries. The HRIR tape recorder failed on November 15, after it had operated for six months, resulting in the loss of stored and direct readout from this subsystem.

The Medium Resolution Infrared Radiometer (MRIR) carried by Nimbus II measured the heat balance of the entire 200 million square miles of the earth daily for the first time. Data from the five MRIR channels were presented automatically on a photographic time-strip chart with geographic reference points. (The data were processed at Goddard Space Flight Center shortly after being received.) The five data channels gave information on water vapor content, surface and cloud top temperatures, stratospheric temperatures, and total earth emitted and reflected radiation. Failure of a tape recorder on July 29, also caused this sensor to cease operating after 2½ months.

When an ESSA I camera failed, Nimbus II real time data became the primary source of global cloud cover information for ESSA in September and October, until ESSA III was launched. Also, Nimbus II APT pictures filled a gap in ESSA's coverage of the northern latitudes during the winter months when ESSA II was in an early morning orbit.

Hardware for Nimbus B (the third in the series) was being developed and the engineering model being assembled and tested. The spacecraft, scheduled for an early 1968 launch, will be the first Nimbus to carry new infrared spectrometric sensors and a meteorological data collection system to gather information on a global scale. Experiments for the fourth Nimbus (Nimbus

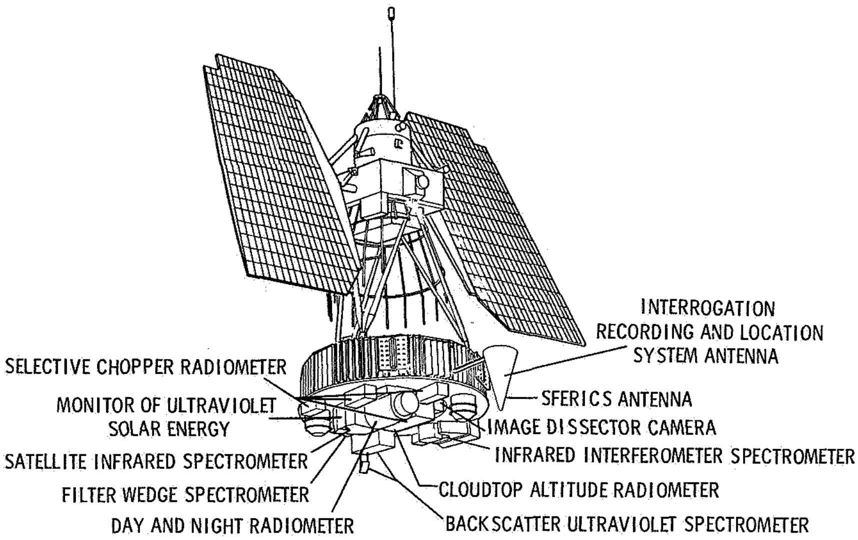


Figure 3–1. Nimbus D meteorological satellite.

D) were selected. (Fig. 3–1.) Eleven of the experiments were approved upon the recommendation of NASA's Space Science Steering Committee from over 20 submitted by scientists to the Committee. Nimbus D, whose control system and data handling and transmission system incorporate technological improvements, is scheduled for a 1970 launch.

Meteorological Sounding Rockets

Meteorological sounding rockets obtain measurements above the 20-mile altitude reached by sounding balloons and below the 100 miles of satellites. In general, three techniques are used to explore the upper atmosphere—light reflecting or luminous vapor, pitot-static tubes, and acoustic grenade experiments.

Five vapor experiments were launched on July 17 from Wallops Station, Virginia, during a 24-hour period to obtain diurnal data for analyzing various modes of motion. Three pitot-static tube experiments—launched from Ft. Churchill, Canada in August along with other experiments—provided continuous profiles of the vertical structure of the atmosphere from the earth's surface to a height of about 200 miles. A series of acoustic grenade experiments launched from Pt. Barrow, Alaska, Ft. Churchill, and Wallops Island, between June and August, studied atmospheric characteristics before and during the period that noctilucent (luminous) clouds were present. And a final series of grenade experiments provided data to study thermally-driven tides. Four were

launched from Wallops Island and five from Natal, Brazil during a one-day period in October.

Also, two launches were conducted for the purpose of developing instruments and techniques. An experimental instrument to measure solar ultraviolet energy was tested successfully in September, and an ozonesonde using a chemiluminescent sensor was launched in December from White Sands Missile Range, New Mexico. Although the parachute failed to deploy properly, payload signals received indicated that the sensor was functioning. This was the only failure in the 26 launches during the last half of 1966.

Operational Sounding Rocket System.—An inexpensive, reliable meteorological sounding rocket system for routine launches, range support, research, and network operations is needed to give adequate coverage of the upper atmosphere. To satisfy this requirement, NASA and the U.S. Army started a joint cooperative program to develop a launch vehicle which will perform better and reduce costs sharply; payloads for the vehicle were also being developed. In addition, the two agencies continued joint development of self-consuming rocket cases in order to reduce or eliminate the falling mass hazard.

In improving payloads, 75 rockets were launched and data was obtained from 75 percent of the launches. In addition to being used for test and development work, the data supported range operations and were made available to other agencies.

Meteorological Experiments on ATS Spacecraft

The first Applications Technology Satellite—ATS I, orbited in December (p. 109)—carried a spin scan camera able to furnish pictures of the visible disk of the earth about every 20 minutes. Figure 3–2 is one of seven pictures taken on December 11 which combined to show the changing cloud pattern over the world that day. Such cloud photographs will be used to observe and study short-lived cloud systems and weather phenomena such as thunderstorms and tornado areas. ATS I is in a geostationary orbit 22,300 miles above the earth and over the equator at 151° West longitude. The satellite views an area from the central part of the U.S. to mid-Australia and from the southern tip of South America to the Aleutian Islands. Since conventional weather observations are inadequate over this area of the globe, ATS I cloud pictures will be very useful for studying weather systems, particularly over the equatorial regions.

A Weather Facsimile (WEFAX) Experiment was conducted which involved relaying weather data from the ATS ground station in Mojave, California, to the Automatic Picture Transmission

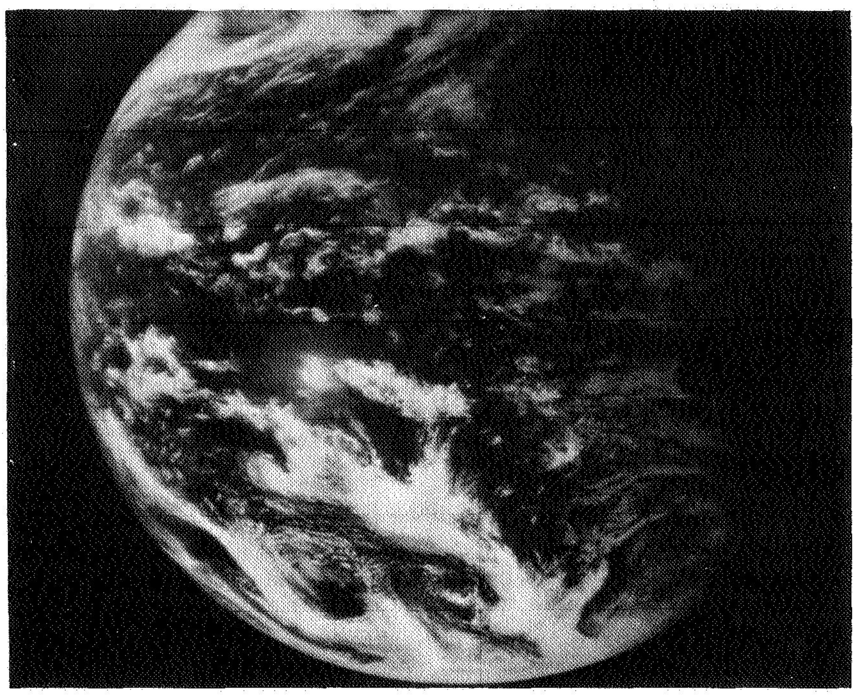


Figure 3–2. World cloud pattern photographed by ATS–1.

(APT) ground readout stations. The test used the VHF transponder on ATS I to relay meteorological data (weather charts, forecasts, cloud analyses, and spin scan camera pictures) from the Mojave ground station to the APT ground stations within communications range of the satellite. Forty-eight APT stations, including stations in four foreign countries, participated in the test transmissions, and the participants considered the data transmitted to be useful and of high quality.

The high and low resolution cameras of the Advanced Vidicon Camera System were mounted on the ATS A flight spacecraft (the second in the ATS series) and were in final integration and checkout. The high resolution camera will take detailed TV pictures of a limited portion of the earth; the low resolution camera will supply photographs of the disk of the earth from the 6500-mile orbiting altitude of the satellite. ATS A will also investigate any perturbing effects of moving parts of the cameras, such as shutters and tape recorder reels, on the spacecraft's gravity gradient stabilization systems.

A spin scan camera experiment incorporating color was approved for inclusion on the flight of ATS C. This camera—similar to the spin scan camera that performed so well on ATS I—incor-

porates filters to provide pictures in three colors. The color will help to determine cloud heights and cloud movements. ATS C will also carry an image dissector camera, an advanced camera system which scans the earth electronically from North to South.

COMMUNICATIONS SATELLITES

Relay and Telstar

Relay II and Telstar II continued working after 3 and 3½ years in space, respectively. Except for communications experiments conducted by foreign ground stations, Relay II was used exclusively to gather data on radiation and radiation effects. Telstar II was not operated during 1966.

Syncom

The Department of Defense used Syncom II and III for operational communications in the Indian and Pacific Ocean areas. Syncom II—launched in July 1963—exhausted its station-keeping propellant in 1965, and now oscillates around the 73rd East Meridian. Syncom III, which exhausted most of its propellant in July 1966, was drifting slowly westward from 160° East longitude. (Syncom III was launched in August 1964.)

Intelsat

Intelsat I (Early Bird)—orbited by NASA for the Communications Satellite Corporation (Comsat) in April 1965—was still being used for commercial traffic across the Atlantic Ocean.

On October 26, 1966, NASA launched the first in the Intelsat II series for Comsat. A failure of the apogee motor resulted in the spacecraft being injected into an inclined elliptical orbit rather than a synchronous equatorial orbit. The satellite has an apogee of 22,300 miles and a perigee of 2,070 miles. It was being used for commercial traffic between Hawaii and the U.S. mainland for five to seven hours daily.

Echo

The passive communications satellites Echo I and II were used for geodetic measurements and air drag studies. No government-supported communications experiments were conducted with these two spheres in the last half of 1966 and none were planned for the future. (Echo I was orbited in 1960; Echo II in 1964.)

Early Gravity Gradient Test Satellite

On June 16, the Defense Department launched the Early Gravity Gradient Test Satellite (GGTS) into a nearly geosta-

tionary equatorial orbit in conjunction with its first group of Interim Defense Communications Satellites. NASA financed and provided technical support in developing this two-axes gravity gradient experimental satellite which demonstrated that the earth's gravitational pull can stabilize spacecraft in high orbits.

APPLICATIONS TECHNOLOGY SATELLITES

NASA launched its first Applications Technology Satellite (ATS B or ATS I) on December 6. In a nearly synchronous orbit, it arrived on station roughly half way between Tahiti and Hawaii December 16. Although most of the experiments carried by the 1,550-pound satellite were operated by December 9, formal experimental testing did not begin until orbital maneuvers were completed on December 20. All spacecraft systems and experiments (except the resistojet experiment scheduled for mid-January) functioned properly, and the spacecraft was being used 24 hours a day for experimental testing.

Successful microwave communications tests were conducted between the ATS ground stations at Mojave, California, Rosman, North Carolina and at Cooby Creek near Toowoomba, Australia. Good quality color TV signals were received at these stations and at the Radio Research Laboratory Station in Kashima, Japan. Also, VHF communications tests were conducted with the Federal Aviation Administration and with commercial aircraft. The first two-way voice communication between a ground station and a commercial aircraft in flight via satellite took place on December 10. All the communications tests were of good quality, and VHF experiments in transmitting weather facsimile pictures to APT ground stations were also highly successful.

The spin scan camera experiment (p. 107) provided excellent photographs of the earth's daytime cloud cover over the Pacific Ocean. Dawn to dusk pictures showed the change in cloud patterns during the course of a day.

Preparations for the second launch in the ATS series (ATS A) early in 1967 were on schedule. Electrical shakedown tests of the prototype spacecraft for this medium altitude gravity gradient mission were completed in October. Environmental qualification testing began in December, and no major problems arose. Flight spacecraft integration was completed, and electrical shakedown tests were in progress as of December 31.

Experiments were selected for the remaining ATS spacecraft (C, D, and E), and all work for them was proceeding on schedule. Feasibility studies for an advanced applications technology mission (ATS F and G) were conducted by three contractors under Goddard Space Flight Center (GSFC) management. The studies

determined that advanced spacecraft stabilization techniques could be used to launch into synchronous orbit an ATS satellite carrying a large parabolic antenna able to point accurately. GFSC received the contractor's final reports in December and was evaluating the feasibility of the various spacecraft designs proposed.

GEODETIC SATELLITES

PAGEOS–I, launched on June 24 into a nearly circular, 2640-mile high polar orbit (*15th Semiannual Report,* p. 74), is a 100-foot diameter sun-reflecting balloon of the Echo–I type. Carrying no instruments, the satellite reflects the sunlight to provide an orbiting point source of light which earth-based observers can photograph to help locate continents, land masses, islands and other geographic points for a unified global geodetic control reference system. PAGEOS was being observed by about 40 stations around the world. Agencies cooperating with NASA in its observational program are the Department of Defense, the U.S. Coast and Geodetic Survey, the Smithsonian Astrophysical Observatory, and several foreign participants.

Another geodetic satellite (GEOS–I, Explorer XXIX)—launched on November 6, 1965—experienced a command system failure on December 1 of this year which resulted in the loss of data from its Doppler, range and range rate, and flashing light systems. However, its SECOR electronic ranging and laser ranging tracking systems continued to provide data. While operating, the satellite provided daily geodetic tracking service to about 110 ground observational stations around the world. The five geodetic observational systems provided over 61,000 optical observations and 32,000 electronic data passes, supporting investigations in geometric and gravimetric geodesy and comparisons in measurements between different systems of instruments.

Geometric measurements have supplied improved positional data for many observers. Gravimetric measurements have helped define some of the more detailed gravity field components which affect significantly the motions of earth-orbiting satellites. A study by NASA's Ad Hoc Advisory Group for Satellite Geodesy indicated that measurements from geodetic satellites will be useful in determining the deformation of the oceans and the solid earth —data which may be applied to earth physics and oceanography.

EARTH RESOURCES SURVEY PROGRAM

In this program, a number of aircraft continued to fly prototypes of spacecraft instruments over test sites gathering data to help scientists demonstrate the feasibility of such measurements

(*15th Semiannual Report*, p. 76.) Among the instrumented aircraft were a NASA plane for conducting tests at altitudes up to 40,000 feet, other types of NASA aircraft, planes of other government agencies, and those of private industry (on a part-time basis). The aircraft—carrying such instruments as infrared imagers, microwave radiometers, radar, and special cameras—flew over 50 test sites offering various earth resources phenomena.

Research data acquired by spacecraft, aircraft, and ground-based instruments were being collected, processed, and stored at the data processing and distributing unit at the Manned Spacecraft Center. At this Center the data was being disseminated to cooperating scientists in government, at universities, and in private industry. In close cooperation with NASA, the Departments of Agriculture, Commerce, and Interior worked to determine the usefulness of the remote data in making earth resources surveys.

Recent studies of remote sensor data applied to agriculture and forestry revealed that crop species and variety; relative size and maturity of the crop; soil type, moisture content, and relative amounts of soil and vegetation; and geometric configuration of the crop often caused a varied response in instruments gathering this crop data. It was also demonstrated that use of several wavelengths simultaneously provided a more reliable method for the correct identification of these crop-related variables.

Preliminary results indicated that infrared imagery and color photography from aircraft could provide data for conducting hydrologic surveys. For example, when an infrared image of the Hilo, Hawaii area was analyzed, it showed cold fresh ground water escaping into the ocean. (A method for locating additional sources of fresh water would be of inestimable value in arid coastal regions in many parts of the world.) Color and infrared photography were also used to map the mixing of pollutants in rivers and lakes—a promising technique for pollution control programs.

In addition, photographs taken by Project Gemini astronauts were used to identify roads, urban developments, and airfields. Frequent updating of such data could be useful in studies of urban development, transportation systems, and population distributions. Also, many large-scale geologic features not apparent on photographs of smaller areas were revealed by the Gemini pictures. An examination of one of these photographs of Iran showed a major fault of recent origin (fig. 3–3). In a North-South direction, it extends for more than 60 miles to the right in the center of the photograph. Since mineral deposits and geologic faults are frequently related, identifying major faults such as this one assists in locating new sources of important minerals.

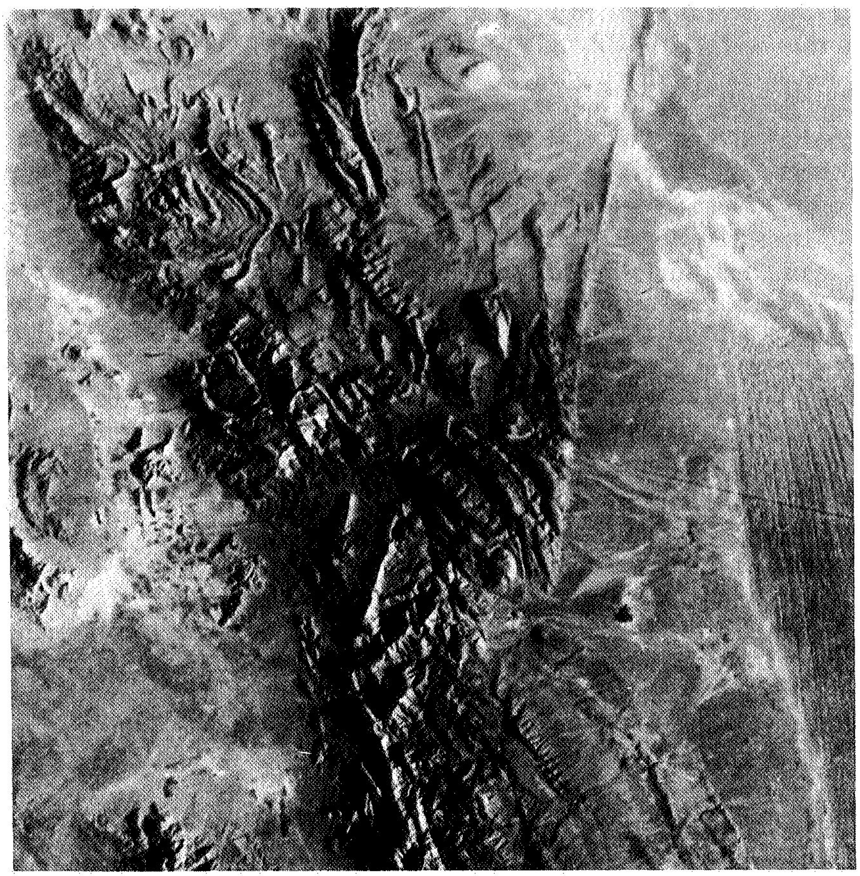


Figure 3–3. Gemini photograph reveals a geologic fault in Iran.

Photographs and infrared measurements from the TIROS and Nimbus satellites were also used in earth resources studies. Nimbus infrared data helped to map major ocean currents and chart ice boundaries in the north and south polar regions. Figure 3–4 is an infrared image from Nimbus II which clearly outlines a portion of the Gulf Stream (the darkest colored areas near the center of the photograph). Information on ocean currents aids the shipping industry in routing its vessels and the fishing industry in charting the movement of fish.

NAVIGATION-TRAFFIC CONTROL SATELLITES

In July, the Federal Aviation Administration (FAA) asked NASA to make available a future experimental satellite able to conduct communications and independent position tests in the UHF band between aircraft and ground stations. The tests would

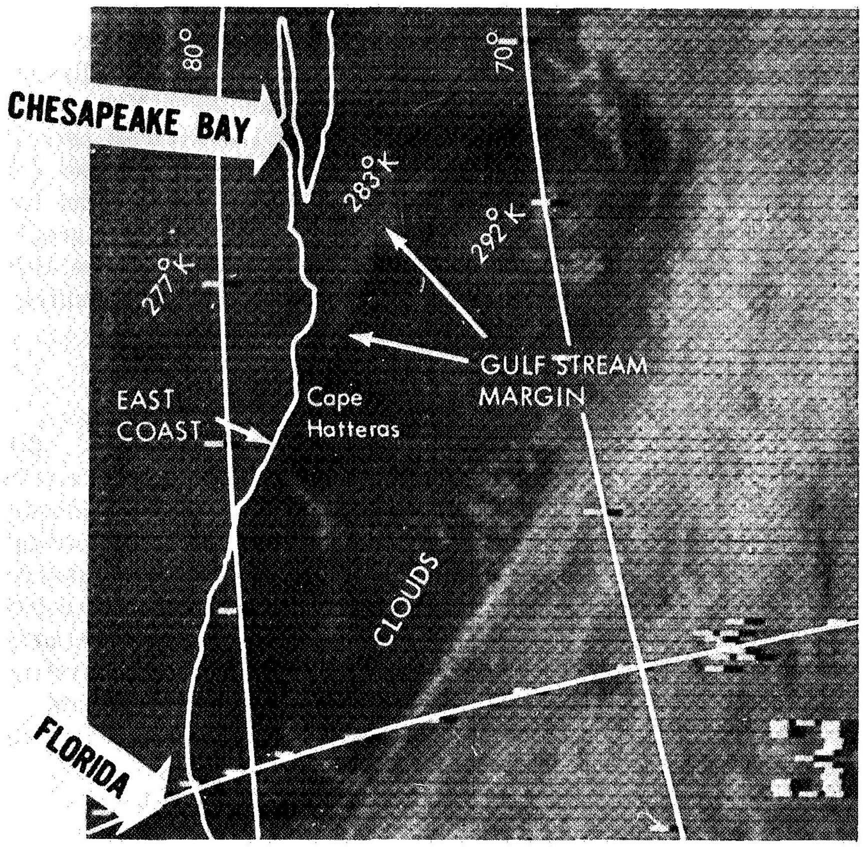


Figure 3–4. Nimbus II infrared image pinpoints Gulf Stream.

be useful in evaluating problems associated with aircraft-to-satellite and satellite-to-ground communications links. NASA's Electronics Research Center will conduct supporting research and technology for navigation satellites—including that needed to meet this FAA request. NASA and the FAA were also investigating techniques for carrying out aircraft navigation and traffic control tests using the *O*mega *P*osition *L*ocation *E*xperiment (OPLE) system under development for the Applications Technology Satellite (ATS–C) mission. The OPLE experiment will use the U.S. Navy Omega ground stations and the VHF transponder on the ATS–C spacecraft.

The study on the possible uses of manned spacecraft for developing navigation technology was completed, indicating that navigation and traffic control experiments could be conducted on Apollo lunar missions in either low or geostationary orbit.

The U.S. Navy, Department of the Interior, National Science

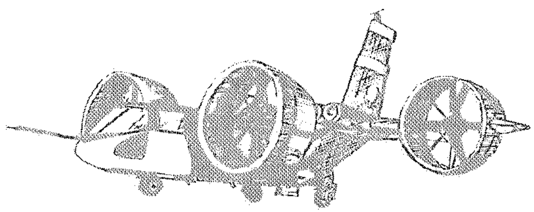
Foundation, and Woods Hole Oceanographic Institute asked to participate in the Interrogation, Recording and Location Systems (IRLS) experiment to be flown aboard the third Nimbus meteorological satellite (Nimbus B) early in 1968. These agencies will provide the IRLS platform, and NASA will furnish data collection and reduction services. The platforms will conduct such tests as locating ocean buoys and collecting their oceanographic data, tracking the movements of animals like large turtles, demonstrating the use of the IRLS in search and rescue operations, and determining the position of a research ship.

MANNED SPACE APPLICATIONS

In developing experiments for its meteorological program, NASA carefully considers exploiting the prime advantages of manned earth-orbiting missions as well as those afforded by the Nimbus, TIROS, ESSA, and ATS automated meteorological satellites. The pictures and data returned by these satellites have helped to detect and track storms. To extend their forecasting periods from 2 or 3 days to 2 weeks, temperature, moisture, pressure, and wind as functions of height must be measured. Systems for Nimbus were being refined to supply this additional data.

The first manned earth-orbiting space applications mission will use a manned flight in every possible way to accelerate the development of experiments and techniques leading to a global weather observation system. Although the Apollo earth-orbital applications missions afford an excellent opportunity to conduct space applications experiments, the concepts must be verified in prolonged orbital flight before they are ready to be applied to long-life, automated meteorological satellites for continuous global data gathering. The 12 meteorological experiments of the first manned earth-orbiting space applications mission should provide data which will contribute significantly to improvements in numerical weather prediction and statistical modeling techniques. Also planned for the flight is a millimeter wave experiment to test new communications techniques and a multiband synoptic camera experiment to make the first earth resources survey from space.

4 ADVANCED RESEARCH AND TECHNOLOGY



In keeping with its assigned responsibility, the Office of Advanced Research and Technology continued to conduct research and to develop new technology for advanced aircraft and space vehicles. This work, divided among the eight technical programs described in this and the following chapter, is carried on in government, university, and industrial laboratories as a cooperative effort which helps the Nation maintain its leadership in aeronautics and space.

SPACE VEHICLES PROGRAM

Space Radiation Protection

The plasma shield (*13th Semiannual Report,* p. 87) is an advanced concept for protecting men and vehicle components against space radiation. It uses a high voltage of positive potential to deflect high-energy protons and a magnetic field, supplied by relatively lightweight superconducting coils, to repel electrons. It offers the advantage of substantial savings in weight where large amounts of shielding are needed. Research showed the basic principles of the concept to be valid, and their application to other devices requiring high voltages was being investigated. For example, the Atomic Energy Commission initiated a study of the feasibility of applying these basic principles in a device capable of accelerating heavy ions to high energies at much less than the cost of conventional methods.

Meteoroid Hazard

The three Pegasus satellites launched in 1965 have now recorded over 1500 meteoroid penetrations. The Pegasus data, along with data from Explorers XVI and XXIII, were used in formulating improved meteoroid design criteria and as the basis for modifying the Apollo design environment to reduce protection requirements.

Operation of the three Pegasus spacecraft was extended beyond the planned cut off times in order to obtain very important data on the reliability of spacecraft systems and systems design. Continued operation and testing of the six identical systems for each major circuit on the spacecraft until failure will furnish data on the expected lifetime and reliability of many standard type circuits.

Reduced Gravity Fluid Behavior

On June 7, a liquid slosh experiment was flown on a 2-stage solid propellant rocket flight to check out the principal portions of the propellant management systems used in the Centaur and S–IVB stages. The experiment, which demonstrated the effectiveness of the system, was followed by completely successful flights of the Centaur and S–IVB stages.

Temperature Control and Thermal/Vacuum Technology

A zinc oxide pigmented silicone thermal control coating in which the stability of the pigment is enhanced by encapsulation in a silicate was successfully used on the second Lunar Orbiter Spacecraft. Efforts to improve the stability of this pigment by chemical treatment or "doping" continued, and studies were made of possible substitutes, including titanium dioxide and zinc titanate. The objective of this work is to achieve longer term stability than is required on Lunar Orbiter.

An all cryogenic pumping system which may eliminate some of the problems associated with oil diffusion pumps in large vacuum chambers was under development at Goddard Space Flight Center. The new system, by using a pumping process which consists of condensing the residual chamber gas on very cold or cryogenic surfaces within the vacuum chamber, eliminates the need for moving parts.

Lifting-Body Flight Program

NASA's two lifting-body research vehicles entered flight status. (Fig. 4–1.) The M–2 and HL–10, each representing a different lifting body design concept, were carried by a B–52 to an altitude

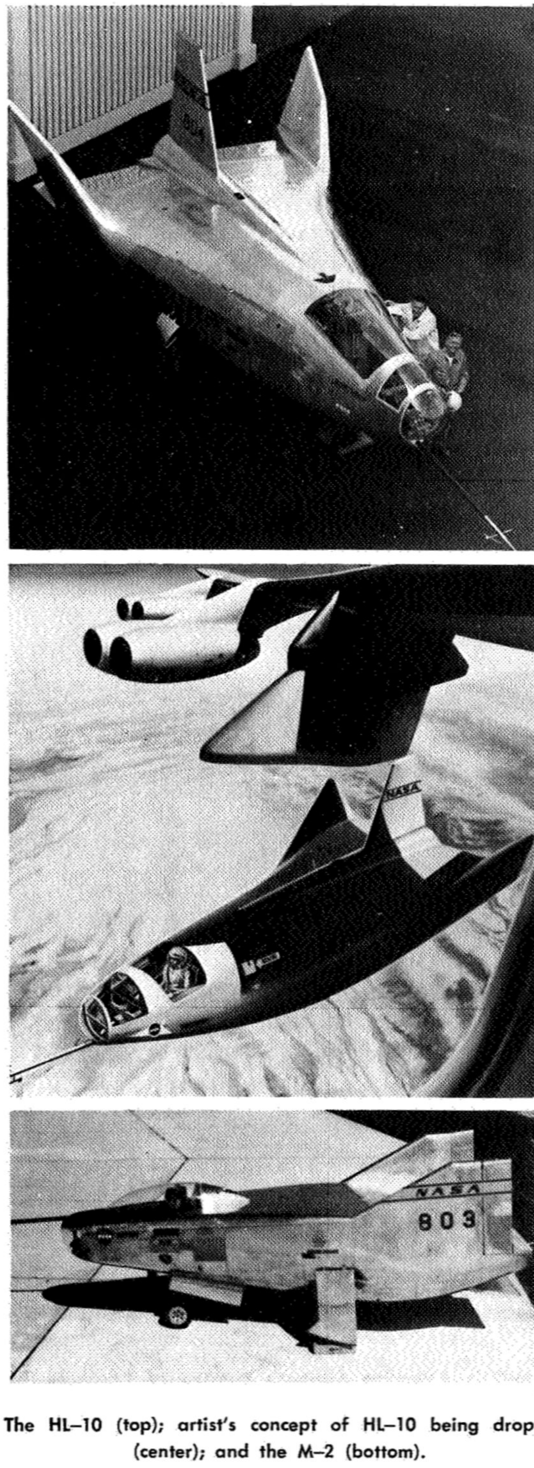


Figure 4–1. The HL–10 (top); artist's concept of HL–10 being dropped from B–52 (center); and the M–2 (bottom).

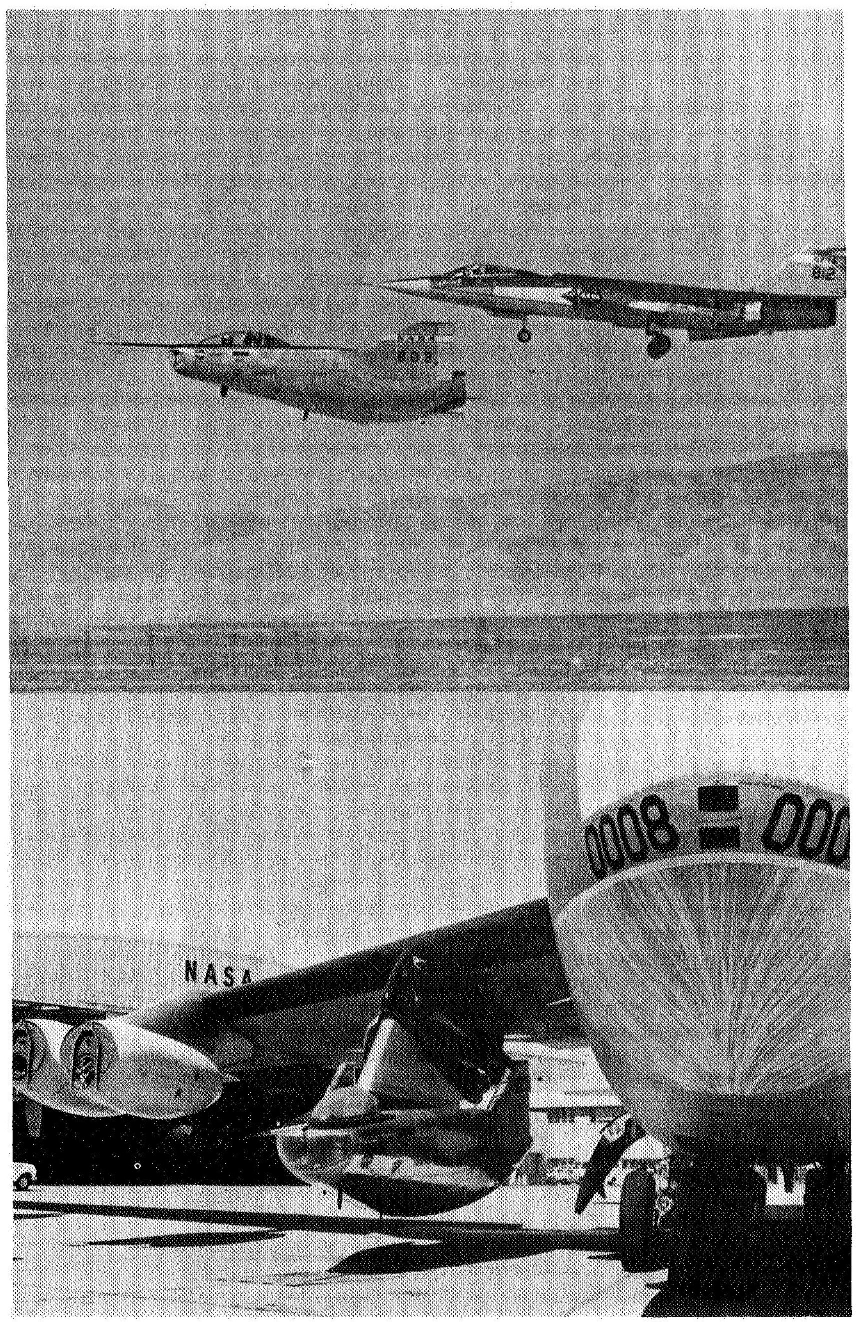


Figure 4–2. The M–2 in a landing approach escorted by an F–104 (top); the M–2 mated to the B–52 launch aircraft (bottom).

of 45,000 feet and released to fly without power and land on Rogers Dry Lake at the Flight Research Center.

The M–2 made fourteen flights, the first on July 12. (Fig. 4–2.) Four were pilot familiarization flights for two NASA pilots and two Air Force pilots, nine were data-gathering flights, and one was made to establish the feasibility of a 360° landing approach for use when rocket engine flight tests of the M–2 and HL–10 begin. The data-gathering flights were made to determine such things as longitudinal and lateral stability and control, control damper (stability augmentation system) settings, longitudinal trim, upper flap effectiveness, lift/drag ratio in flight, instant L/D rocket effectiveness, and general vehicle performance, handling, and landing characteristics.

The HL–10 was flown for the first time on December 22, to check out the vehicle and familiarize the pilot with its flying and landing qualities.

The lifting bodies behaved well in the tests which showed that such configurations can be controlled by the pilot and landed at preselected sites.

Planetary Entry Parachute Program

A Langley Research Center flight and laboratory research program is investigating parachutes that can be used for soft landing an instrumented capsule on Mars. Large balloons and rocket-launch vehicles carry test spacecraft and test parachutes to high altitudes where the atmospheric density is close to that near the surface of Mars. At such altitudes, 120,000 to 140,000 feet, the test parachute is deployed behind a representative Mars entry capsule to study the deployment and inflation characteristics of the parachute under realistic flight conditions. One balloon flight, using an 84-foot parachute, and two rocket-launched flights of a smaller test vehicle with a 30-foot parachute were completed. Four additional balloon flights and seven rocket-launched flights were planned for 1967. The results of the program indicated that parachutes offer a reliable and simple means of controlling and decelerating an entry capsule for landing on the Martian surface.

Structural Loads

One of the problems associated with the design of launch vehicles is the lack of reliable data for predicting the response of the vehicle to ground winds. Such winds, blowing across the vehicle on the launch pad, produce alternating side forces that cause the vehicle to oscillate sideways. The lateral motion can cause stresses near the base of the vehicle in excess of those for which it was designed. To offset the lack of data, reduced scale dynamic

models were tested in a wind tunnel at Langley Research Center. Tests of a Saturn V model showed an excessive lateral response, but they also indicated that only a moderate increase in damping would reduce the motion to an acceptable level. As a result, a viscous damper was installed on the launch complex to provide damping between the vehicle and the launch umbilical tower.

Structural Dynamics

The *13th Semiannual Report* (p. 92) discussed the increase in compressive strength of longitudinally stiffened cylinders achieved by attaching the stiffeners to the external surface of the shell. Further investigations of external stiffeners showed that shell stiffness, as well as strength, can be considerably increased. For one range of shell parameters, the fundamental structural frequency was increased as much as 35 percent. Since frequency is an important vehicle design parameter, the ability to increase it without increasing structural weight is extremely significant. However, at present, external stiffeners are being considered only for configurations where aerodynamic smoothness is not a requisite.

Space Vehicle Design Criteria

The NASA program to develop uniform design criteria which will ensure flight worthiness of space vehicles and components progressed with the assignment of responsibility for environment studies to Goddard Space Fight Center. Other centers continued to carry out their responsibility for producing criteria documents in structures (Langley), chemical propulsion (Lewis), and stability, guidance, and control (Electronics Research Center). The purpose of this program is to collect, assess, and digest technical and scientific information and from it to develop and publish authoritative design criteria using technical specialists from Government, industry, and the universities.

SPACECRAFT ELECTRONICS AND CONTROL

Electronic Techniques and Components

In research at the Electronics Research Center, a thin-film, space-charge-limited triode was fabricated, and prototype models were tested with good results. Such devices will make it possible to produce circuitry with a higher tolerance to space radiation, the ability to withstand higher temperatures, and enhanced reliability achieved by eliminating several processing steps.

A Langley Research Center contractor developed a micropower

(250 microwatt) microelectronic family of logic circuits which effectively reduced power consumption by a factor of ten; prototype units were being evaluated. The importance of such devices lies in the fact that they will permit the number of logic circuits used on deep space missions to increase as necessary without causing the weight and volume of the power supply systems to outstrip those of the electronic systems they supply.

Guidance and Navigation

Simulator studies of the feasibility of making accurate hand-held sextant (Fig. 4–3) measurements for space navigation were confirmed by flight experiment on the Gemini XII mission (November 11–15, 1966). Sightings on two stars with the astronaut's helmet off resulted in an average error of 6.6 arc seconds; with the helmet on, the error increased to 7.5 arc seconds. In addition to confirming the simulation studies, the experiments also demonstrated the potential of a hand-held sextant as a backup to automated instruments or as a primary navigation instrument for lunar and planetary missions. Further experiments were planned for an Apollo development flight.

Control Systems

Attitude control of manned spacecraft moved ahead with the development of a control moment gyro (CMG) system by the Langley Research Center. (Fig. 4–4.) This system, which will be used first on the Apollo Telescope Mount flight, provides precise pointing of the telescope without the gas contamination of reaction jet control. The CMG uses a constant speed flywheel, which stores momentum when operating and is oriented by two gimbals. As the flywheel spin axis is realigned by means of low powered torque motors, the momentum creates a torque reaction on the vehicle, causing it to reposition. Thus, the space vehicle is controlled and stabilized in attitude. The CMG system also offers a weight advantage, which is meaningful for 30-day and longer missions.

A program was initiated to conduct research on flight control equipment for general aviation aircraft. Its objective is to develop improved but relatively inexpensive navigation and control devices. One development from the program was a fluidic autopilot system prototype which was installed in an Aero Commander for flight evaluation. (Fig. 4–5.) With over 20 test flights completed, performance of the system approached that of more expensive electronic systems, but further work was scheduled to improve sensor characteristics and reliability.

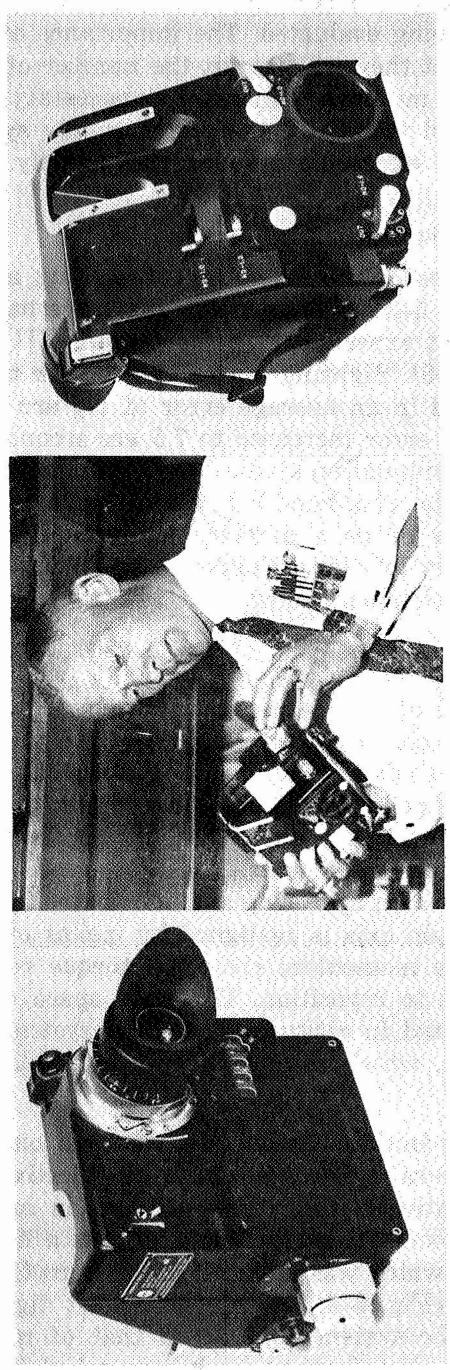


Figure 4–3. Astronaut Edwin E. Aldrin, Jr., inspects the hand-held sextant. Front view (left); rear view (right).

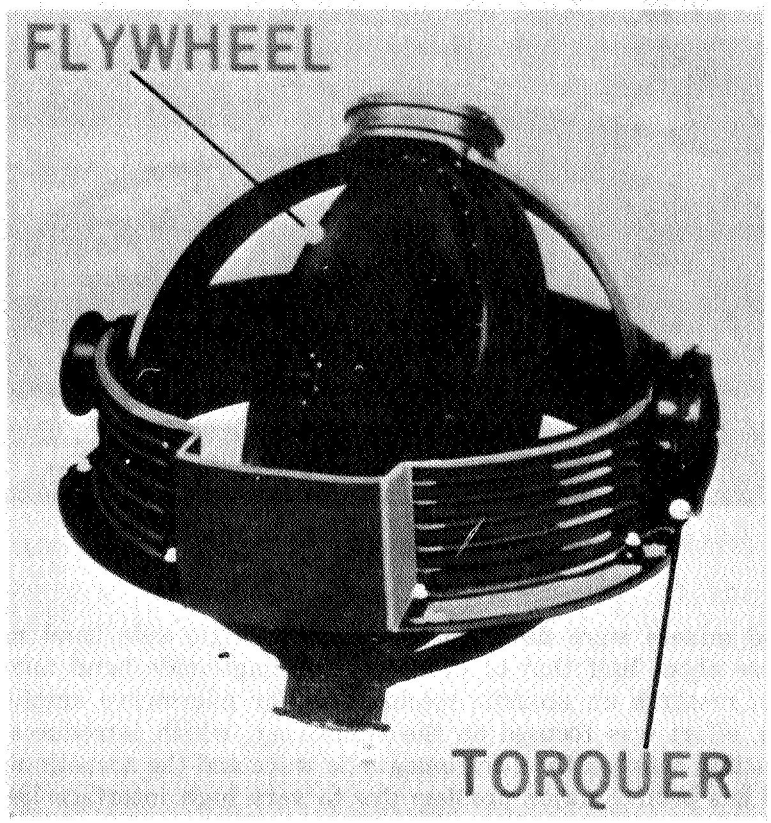


Figure 4–4. Control moment gyro.

Communications and Tracking

The Electronics Research Center sponsored research on solid state devices in an effort to develop lighter weight, more efficient, and more reliable communications and telemetry receivers and transmitters for deep space and earth orbital applications. Progress was made in using computers to design varactor frequency multipliers for spacecraft transmitters. Tuning adjustments on the circuits were eliminated by tailoring the design to achieve the optimum impedance at each frequency. An experimental S-band, bridge-circuit multiplier transistor oscillator was designed and constructed for 100-watts continuous wave output at an overall efficiency of 50 percent—an order of magnitude better than current solid state radio frequency power sources.

For spacecraft receiver applications, balanced S-band and X-

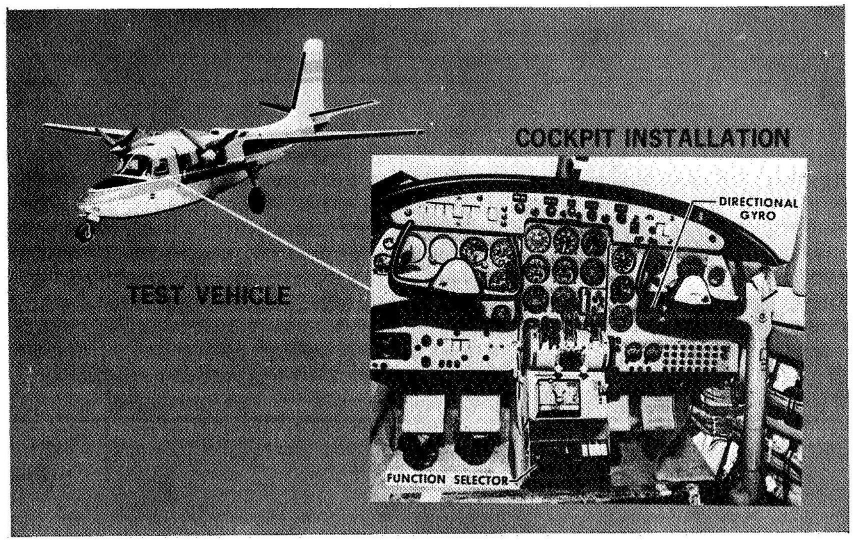


Figure 4–5. Fluidic flight control system.

band mixers were designed to obtain a single side band noise figure about half that of other crystal single side band mixers.

In research on acoustic mechanisms for microwave amplification, effort was focused on the transducer, which introduces interaction between the electromagnetic wave and the acoustic wave and has been a major problem due to very high interface losses. This work yielded transducers with such losses reduced by a factor of 1000, demonstrating the practicality of microwave acoustic amplifiers and opening the way to research in other signal processing functions.

Data Processing

Investigators at Marshall Space Flight Center demonstrated the feasibility of an advanced spacecraft computer memory which uses the magneto-optical properties of a gadolinium iron garnet crystal to achieve extremely high storage capacity, high reliability, small size, and a minimum of interconnections. (Fig. 4–6.) Crystal construction techniques limited the bit packing density for this type memory to about one million bits per square inch; however, studies showed that additional research may make it possible to realize a hundred-fold increase in packing densities. Work at the Electronics Research Center indicated that advances in microelectronics and batch fabrication techniques may make it possible to apply time sharing, on-line computing functions and multiprocessing concepts to spacecraft use. Studies of methods of

arranging computers to serve spacecraft functions showed that the multiprocessing arrangement (right side, fig. 4–7) is superior from the viewpoint of cost effectiveness, weight, and reliability to the autonomous and centralized systems. Further research was scheduled to develop similar concepts for spacecraft applications.

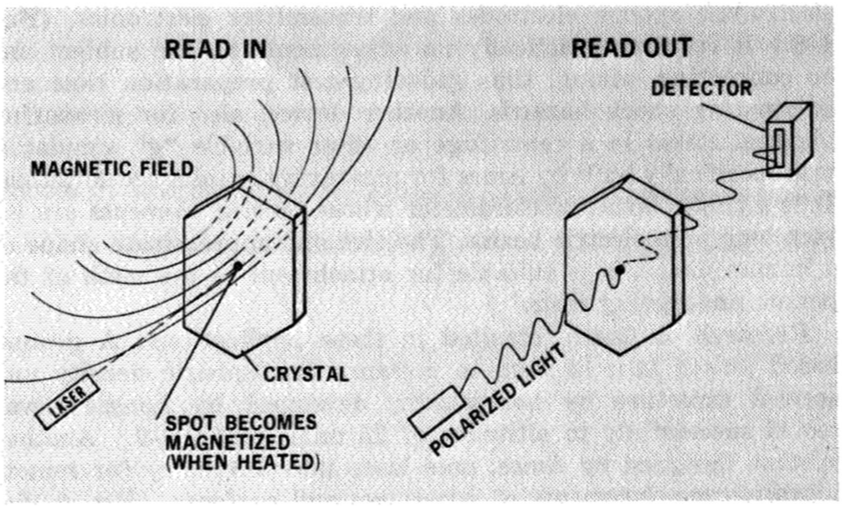


Figure 4–6. Computer memory structure.

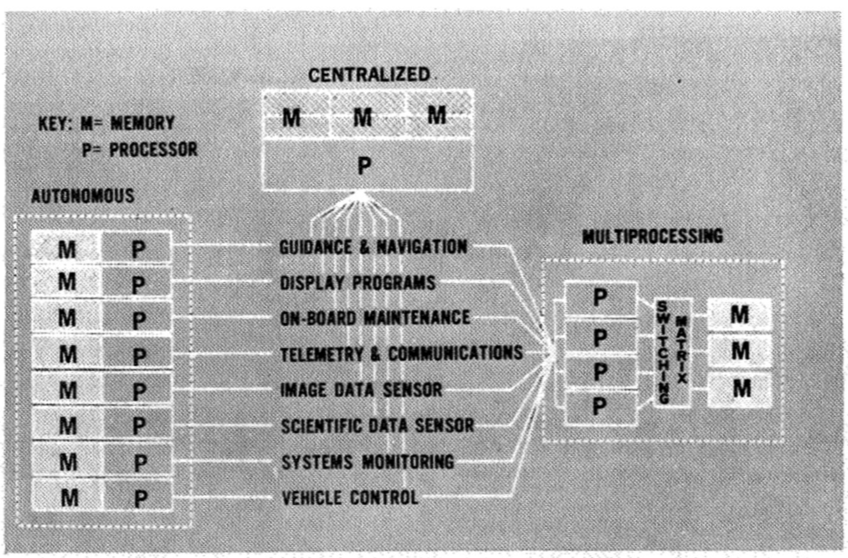


Figure 4–7. Spaceborne computer concepts.

Instrumentation

Research in bioelectronics produced improved methods of measuring human stress under test conditions in simulators, centrifuges, and aircraft. One, a monitoring system for obtaining electroencephalograms developed by Ames Research Center, was designed as an integral part of a flight helmet with built-in electrolytic sponge electrodes and transmitter electronics. (Fig. 4–8.) It requires practically no adjustments by the subject and no connecting wiring, thus reducing test preparation time and eliminating shock hazards. Another device, also for measuring physical stress in a centrifuge or other variable "g" simulator, was specifically built by Ames for measuring cranial accelerations. It is a tiny triaxial accelerometer whose sensing elements are 0.2 inch long piezoelectric beams. The size and approximate shape of a human molar, it is suitable for attachment to the teeth of the person undergoing tests.

Research on lasers resulted in these applications: A ground based pulsed laser system to measure atmospheric density and aerosol structure by backscatter, developed by Langley, was tested successfully to altitudes of 25 miles. (Fig. 4–9.) Another system, designed by Ames, uses laser interferometry for remote vibration measurements of structures and surfaces. (Fig. 4–10.) The system eliminates the need for attached vibration sensors and, when refined, will permit measurements of amplitudes down to one hundredth of one millionth of an inch. Finally, Marshall

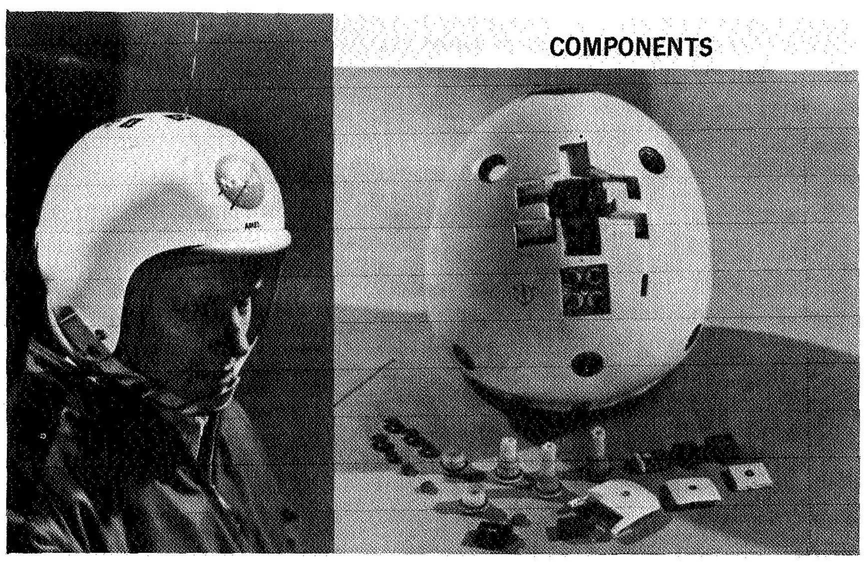


Figure 4–8. Instrumented helmet and components.

used laser scattering to measure localized gas flow velocity in wind tunnels. (Fig. 4–11.) By determining the frequency differ-

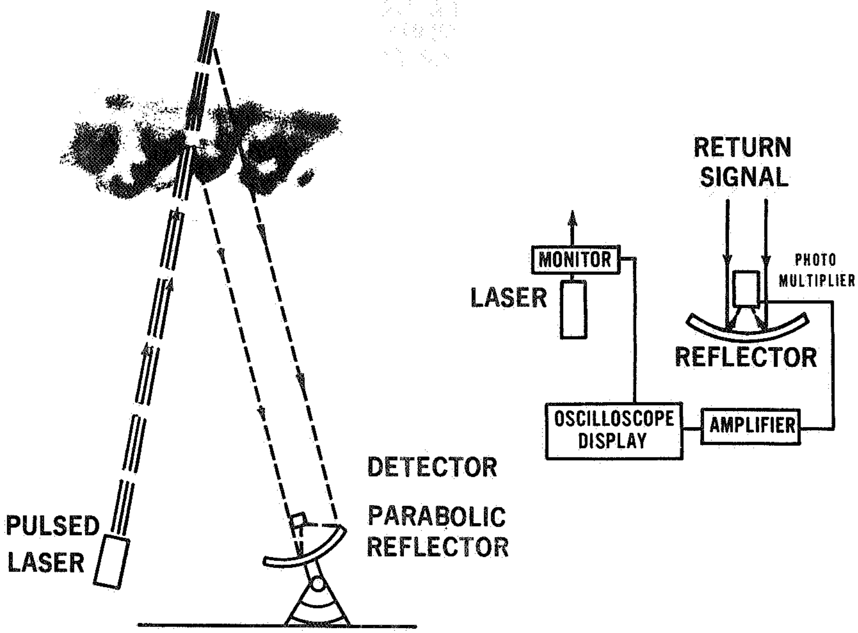


Figure 4–9. Laser measurement of atmospheric density. Major system units (left); Electronic-optical schematic (right).

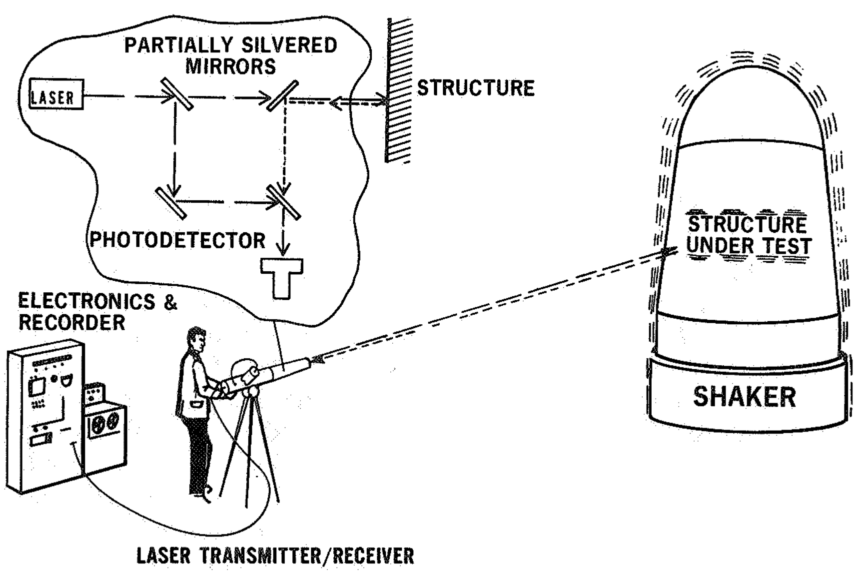


Figure 4–10. Measuring vibration by laser.

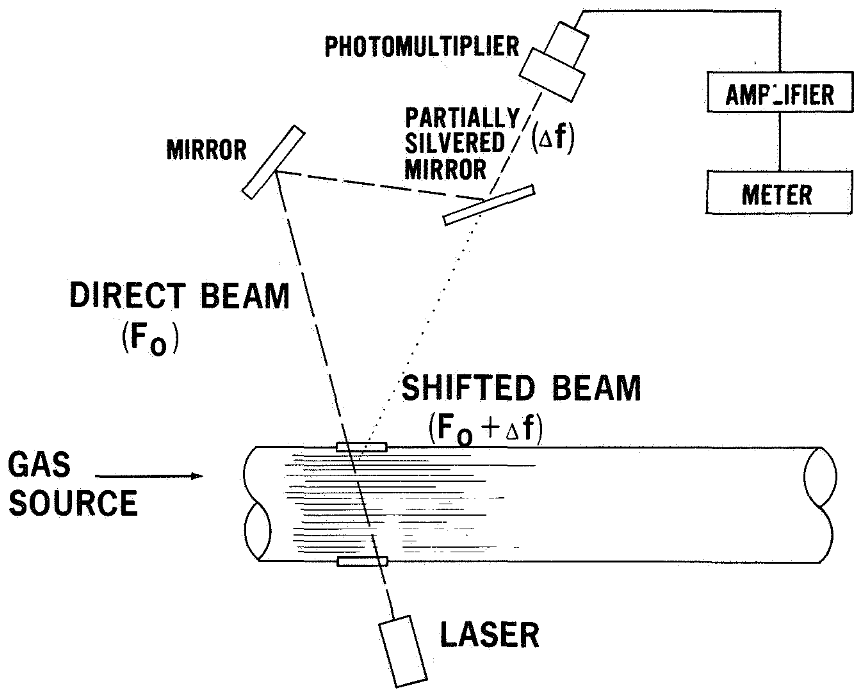


Figure 4–11. Measuring gas velocity by laser.

ence between scattered and unscattered beams, investigators measured velocities over a range of 1 centimeter per second to more than 300 meters per second. This method eliminates sensing devices and their disturbing effect on the gas stream and gives reliable velocity measurements.

AERONAUTICAL RESEARCH

Aircraft Aerodynamics

Theoretical and experimental studies of the aerodynamic characteristics of thin sharp-edge delta wings showed that at subsonic speeds the leading-edge separation vortex which occurs on wings having sharp, highly swept leading edges results in an increase in both lift and drag. However, up to now no completely satisfactory method of predicting the effects of separation vortex flows on the lift of delta wings had been developed. In recent research, a concept was developed for calculating the vortex lift of sharp-edge delta wings, and the theoretical results were compared with available experimental data. For an angle of attack extending to 25° and aspect ratios ranging from 0.5 to 2.0, agreement between the theory and the experimental data was excellent.

Flight tests of subsonic transports with jet engines mounted at the rear of the fuselage and the horizontal tail on top of the vertical tail indicated that airplanes having this general arrangement may inadvertently pitch up to angles of attack above that for wing stall. Tests were conducted on a large-scale subsonic transport model to determine its post-stall static longitudinal stability and control characteristics and to investigate ways of improving them. The static longitudinal stability and control effectiveness of the model was reduced substantially at angles of attack above that for wing stall. The nacelles did not decrease the longitudinal stability and control effectiveness of the model for angles of attack up to 30°, but did reduce stability at larger angles. Small changes in the nacelle locations or deflections of the trailing edge flaps did not significantly improve longitudinal stability or control effectiveness, but leading-edge slats with or without trailing-edge flaps did improve both at angles of attack above the wing stalling angle.

Aircraft Structures

Research continued with an experimental study of aircraft external skin panel flutter in a Mach 3 supersonic wind tunnel having realistic airstream temperatures. A theoretical study of the flutter behavior of flat isotropic panels was carried out to establish the effects of in-plane stress and degree of rotational restraint at the panel edges. Agreement between experimental and theoretical results was good for panels in which the thermal stresses were low. For more highly stressed panels, close to buckling, agreement was poor.

In a related study, predictions of panel flutter characteristics were made by means of two-dimensional static (approximate) aerodynamic theory and linearized three-dimensional unsteady inviscid (exact) aerodynamic theory. Comparison of the theoretical and experimental data indicated that where the approximate aerodynamic theory furnished results at variance with test results, the exact theory failed to provide significantly more accurate predictions. It did, however, point up the important effect of structural damping on flutter.

A wind tunnel study was conducted of the flutter characteristics of models dynamically representative of the wing and horizontal tail of a variable swept wing airplane. Test results at speeds up to Mach three indicated the most critical regions of flutter and the effects of sweep angle.

An exploratory flight research program and analytical investigation was made of the structural load characteristics of a helicopter hingeless rotor system. (Fig. 4–12.) The hingless rotor

Figure 4–12. The H–51 hingeless-rotor research helicopter.

concept eliminates the flapping and lagging hinges by mounting the rotor blades directly to the rotor drive shaft. The flight tests revealed that the structural load of most concern during maneuvers was the oscillatory bending moments in the rotor plane and that a simplified method of calculating the bending moments was reasonably accurate. The hingless rotor would be a significant advance in helicopter design since it would improve control and handling qualities, and reduce rotor-hub complexity, maintenance, and hub aerodynamic drag.

Noise Abatement

Aircraft noise research efforts were greatly expanded in response to the program established by the Inter-Agency Aircraft Noise Abatement Committee. Industry proposals for a fan-compressor noise study were evaluated, but source selection was not completed. The study calls for flight testing the most promising designs for suppressing fan-compressor noise and evaluating the economic aspects as well as the noise suppression characteristics of acoustic treatment and a choked inlet system. An additional $3,000,000 was reprogrammed to fund the first year's study.

Airborne Laser Tests

A study to establish the feasibility of using a pulse ruby laser system for in-flight detection of clear air turbulence, a continuing hazard to aircraft operations, was completed by the Langley Research Center. The results confirmed theoretical estimates of

atmospheric backscatter but also proved that such a laser system could not be used to detect clear air turbulence, since the returns to the airborne system were unaffected by the turbulence encountered by the test aircraft.

Take-off and Landing Simulation

A ground-based simulator with an external visual display was used to simulate a current turbojet transport undergoing certification take-off maneuvers. The tests covered accelerate-stop performance, three-engine take-off, take-off with incorrect trim, minimum unstick speed, ground minimum control speed, and air minimum control speed. The data correlated very well with actual flight test results, and the participating NASA, FAA, and airplane manufacturer pilots agreed the simulator duplicated the performance and handling qualities of the aircraft.

X–15 Research Aircraft Program

Of 18 flights made in this period, seven went to altitudes over 200,000 feet, including one which reached 306,900 feet. Major Michael J. Adams, USAF, became the twelfth pilot to fly the X–15 aircraft, joining John B. McKay, NASA, Major William J. Knight, USAF, and William H. Dana, NASA, as the current X–15 pilots. (Fig. 4–13.)

On November 18, the modified X–15–2 was flown to a new maximum velocity for manned aircraft, 4,250 mph (Mach 6.33), exceeding the previous maximum by 146 mph (Mach 0.27). The flight provided information on the aircraft handling characteristics with full external tanks; external tank separation characteristics; the ablative material required for later flights approaching Mach 8; local flow conditions in the area to be occupied during later flights by the hypersonic ramjet engine; and fuselage base-drag.

In addition to the velocity build-up flight of the X–15–2, the aircraft were used for the following investigations:

X–15–1.—Micrometeorite collection; horizon scanner development; sky brightness and rarefied-gas experiments at high altitudes; reaction control augmentation system checkout; evaluation of a window shade and non-glare glass on the cockpit instruments to aid the pilot during high altitude flights; and determination of total electrical loads in flight, required because of the addition of several new experiments.

X–15–2.—Stellar ultraviolet photography experiment; ablative material test (required for flights faster than Mach 6); fuselage base-drag study; development of an alternate pitot static pres-

Figure 4–13. Major Knight and the X–15.

sure system for flights above Mach 6; and determination of ventral-on stability and control characteristics.

X–15–3.—Checkout of a new inertial flight data system; evaluation of a new cockpit instrument panel using tape displays; measurement of boundary-layer noise, heat transfer, and horizontal tail loads; micrometeorite collection; and solar spectrum and sky brightness measurements.

At the end of the year, the three X–15 airplanes had been flown 176 times, including 133 flights at speeds of Mach 4 and above.

Supersonic Transport

NASA assisted the Federal Aviation Administration over a period of several months in evaluating the two contractor proposal for the U.S. Supersonic Transport. Seventy-five NASA personnel served as members of the Source Selection Evaluation Group. The majority were assigned to the engine and airframe groups, the remainder to safety, reliability, and other related groups. Concurrently, controlled wind tunnel tests of the contractor models were conducted in various NASA facilities, and the results were

furnished to the appropriate evaluation group. For research on the supersonic commercial air transport, an F106B supersonic aircraft was obtained from the Air Force. It will be used for studies of the complex inlet-engine-nozzle dynamics problem, particularly during transonic speed operations (Mach 0.9 to 1.5).

V/STOL Aircraft

A program was inaugurated at the Langley Research Center to provide large-scale systematic aerodynamic design data on the tilt-wing propeller-driven V/STOL airplane. (Fig. 4–14.) The investigation was made with a large-scale, propeller-driven model with a half-fuselage and a single propeller on the semispan wing. The wing had a chord-diameter ratio of 0.5, a double-slotted flap, and a slat leading-edge flow-control device. Angles of attack ranged from 0° to 90°, and tests were made with both left- and right-hand propeller rotation. Lift, drag, and pitching moments were measured, and the flow was observed by means of tufts on the upper surface of the wing and on the fuselage. When leading-edge-flow-control devices were not used, the direction of propeller rotation significantly affected the lift and descent capability; with such devices, either mode of propeller rotation gave approximately the same results. Flap deflection was very effective in increasing the descent capability for either mode of rotation.

Figure 4–14. The XC–142A tilt-wing airplane.

A jet ejector system for augmenting the lift of fixed wing aircraft for vertical take-off and landing is used on the Lockheed XV–4A. (Fig. 4–15.) The full-scale aerodynamic characteristics of this aircraft and its ejector system were investigated in the Ames 40- by 80-foot wind tunned under conditions ranging from hover to conventional wing-supported flight. Ejector performance, longitudinal characteristics, lateral-directional stability and control, and control power about all three axes were determined at various airspeeds and control settings through the transition flight regime. In general, the aircraft had nearly neutral longitudinal stability at angles of attack below wing stall, but above wing stall, pitch-up was severe. Lateral and directional stability were positive. Control power for trim in transition appeared to be adequate except for recovering from post stall pitch-up. Results from small-scale wind tunnel, full-scale wind tunnel, and flight tests generally agreed well.

Following a number of large-scale force-test investigations of the gas-coupled high-bypass-ratio lift-fan concept in the Ames 40-by 80-foot wind tunnel, a fan-in-wing flight-research aircraft—the XV–5A—was developed. (Fig. 4–16.) An approximately 0.18 scale model research aircraft was tested for dynamic

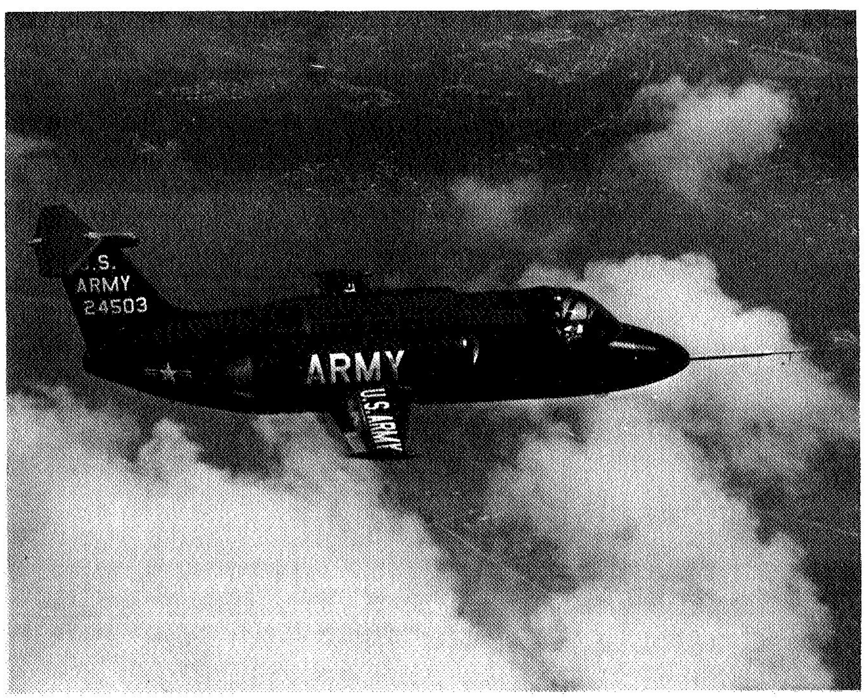


Figure 4–15. The XV–4A.

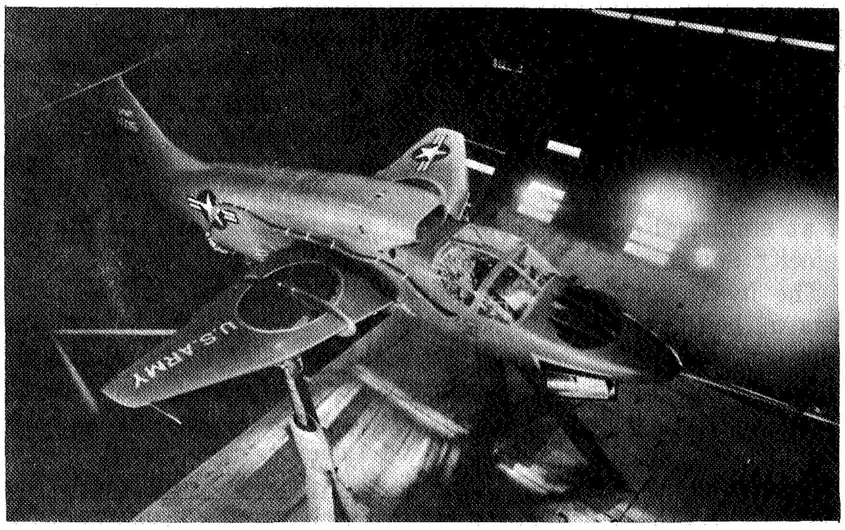


Figure 4–16. The XV–5A in the Ames wind tunnel.

stability and control characteristics in hovering and transition flight. The flying-model investigation was conducted in the Langley full-scale tunnel; flight-test data were obtained mainly from pilot observations and motion-picture records of the flights.

In the hovering-flight tests out of ground effect, with the controls fixed and without artificial stabilization, the model developed unstable oscillations in pitch and roll. It was easy to control in pitch but difficult to control in roll during hovering and low-speed forward flight as a result of its sensitivity to disturbances. It required an increasing nose-down pitch trim during the early part of the fan-powered forward flight but was easy to control in yaw at all airspeeds tested.

Small scale research showed that a significant jet-induced lift loss may occur at zero wind conditions out of ground effect on jet VTOL aircraft when the jet exhaust is directed through the bottom of the fuselage or wing lower surface. In test simulations, lift losses of the order of 1 to 4 percent of the total engine thrust were experienced. The number and arrangement of the jet exhaust nozzles were found to be very significant factors, and it was also theorized that the turbulence in the jet exhaust would cause a lift loss. Using an actual jet-engine exhaust as the test medium, turbulence, temperature, and impact pressure of a jet VTOL aircraft were simulated at reasonably large scale; the nozzles exhausted through square flat base plates representing the bottom of a VTOL airplane.

For single-exhaust-nozzle configurations the induced lift loss

was about 0.5 percent of the total installed thrust; for a multiple-nozzle configuration the losses were about three times this value. It was also found that the jet-induced lift losses of the large-scale turbojet-powered configuration could be adequately simulated by small-scale cold-jet models and that lift losses could be calculated within about plus or minus 20 percent by means of an empirical expression based on the rate of decay of the jet velocity downstream of the nozzle.

The instrument display requirements for low-visibility landings of helicopters and other V/STOL aircraft depend on the approach task (comprising the approach slope, the approach airspeed, and the breakout ceiling) and on the controllability of the aircraft at the approach speed. In order to avoid excessive rates of descent, the airspeed must be decreased as the approach path is steepened; for a given glide slope, the airspeed must also be decreased as the breakout ceiling is lowered. As airspeed is decreased for landing, controllability deteriorates. At the same time, the information requirements for guidance and control increase as the control of the aircraft becomes more difficult. Thus, the instrument display problem becomes increasingly complex for steep approaches to low breakout ceilings. In an investigation of the instrument display requirements for landing V/STOL aircraft, NASA used a helicopter to test a landing-approach display incorporating a cross-pointer presentation. (Fig. 4–17.) The display consisted of a vertical-situation flight-director indicator, a horizontal-situation indicator, and small vertical-scale instruments for the indication of airspeed, ground speed, vertical speed, range, and height. The tests were conducted under simulated Instrument Flight Rules conditions along a 6° glide slope at approach speeds of 30 to 60 knots.

Four configurations of the attitude-guidance elements and four of slope guidance elements of the display were tested. Using the best combination of course and slope guidance displays, one pilot flew 20 (out of 22) thirty-knot approaches to a 50-foot breakout and visual slowdown to hover. Further tests must be conducted before the displays can be considered suitable for operational use.

XB–70 Flight Research Program

Following the loss of the XB–70 Number 2 in a mid-air collision (June 8, 1966), the joint USAF-NASA XB–70 Flight Research Program, which began on June 16, 1966, was replanned around the XB–70 Number 1. The aircraft was modified by installing additional research instrumentation and updating the airplane structure, landing gear, and several subsystems. This

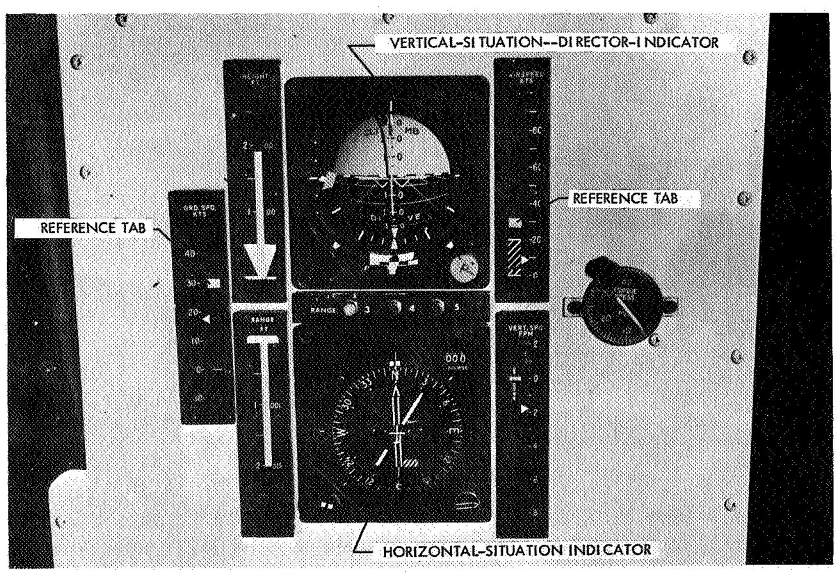


Figure 4–17. Aircraft (top) and instruments (bottom) used in tests.

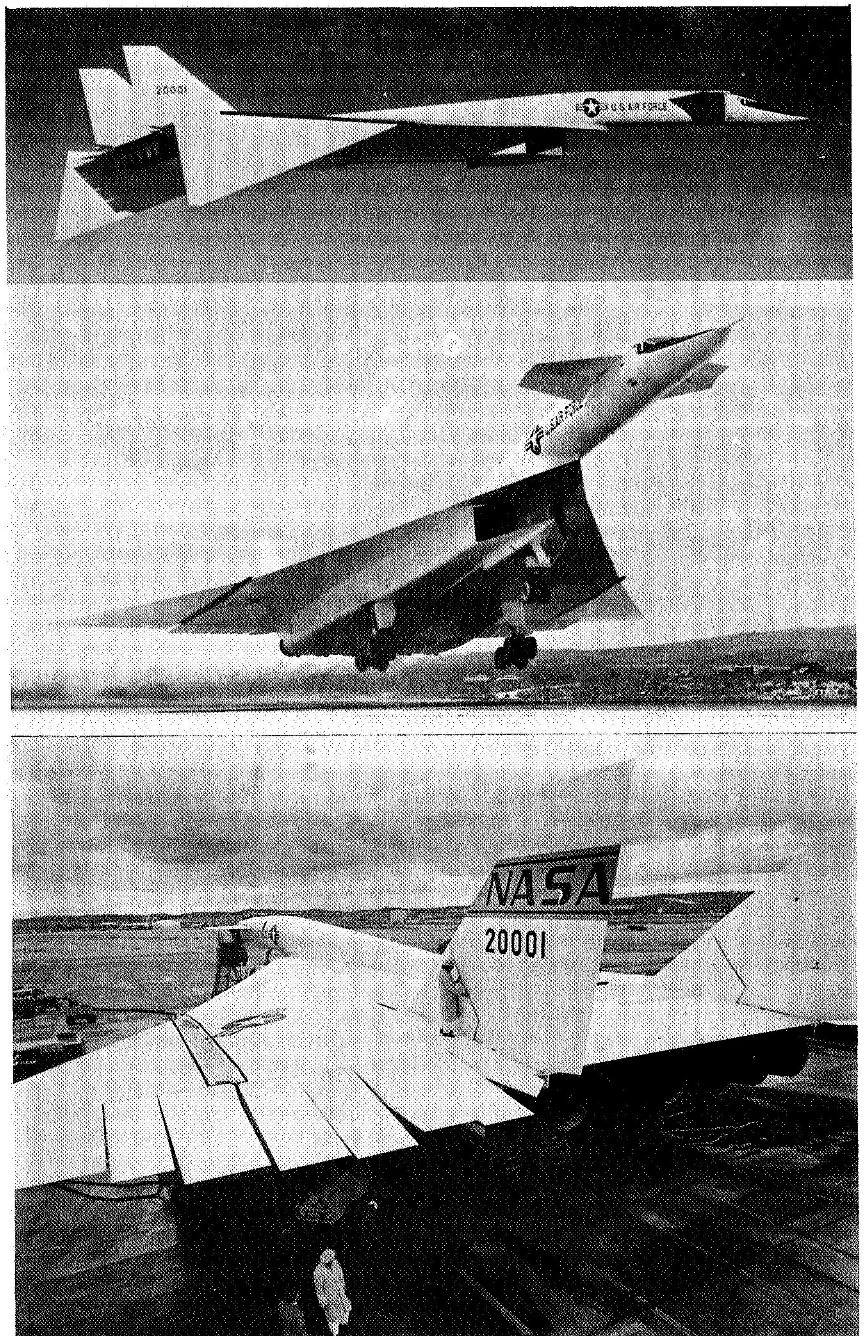


Figure 4–18. The XB–70.

work was completed by early November, and the first flight was made on November 3. (Fig. 4–18.)

The first nine flights of the airplane were scheduled to obtain data on sonic booms for the National Sonic Boom Evaluation Program. On each of the 6 flights completed in this period, the structural response of two houses of average frame construction and the response of discretely placed human subjects were recorded. Test conditions varied from Mach 2.5 at 60,000 feet (5 runs) to 1.5 at 37,000 feet (4 runs), including 2 runs at Mach 1.8 at 60,000 feet. For comparison, a B–58 and an F–104 aircraft passed over the test site at specified flight conditions and time intervals before and after the XB–70 passes.

The flights also provided information on pilot ratings of longitudinal and lateral-directional handling qualities; stability and control data for the landing-approach configuration; photos of tufts showing aerodynamic flow over the wing and vertical tail surfaces for use in studies of the adverse yaw problem of the airplane; and digitized calibrations of two airspeed heads.

Hypersonic Aircraft

Heat transfer investigations were made on a model simulating the leading edge of a lifting surface or engine inlet of a hypersonic aircraft. The tests, performed at Mach 14, measured average heat transfer rates in small localized regions on the stagnation line of the unswept leading edge. With shock waves (generated by a sharp flat plate attached at the root chord of the leading edge plate), heat transfer rates were more than ten times the value without shock impingement. The experimental results suggested that this extreme interaction-induced effect on heat transfer is associated with the impingement of a vortex sheet or slip line (generated at the intersection of the bow shock wave of the leading edge model and the impinging shock wave) onto the leading edge. Heat transfer rates 2½ times the corresponding undisturbed value were measured over large spanwise segments of the stagnation line with the leading edge swept 45°. At this sweep angle, the interaction-induced increase in heat transfer is not a localized result of the shock impingement similar to that found at zero sweep, and heat transfer in the interaction region can be adequately predicted by boundary layer theory. Intermediate values of maximum heat transfer were obtained with the leading edge swept 22.5°; they are apparently associated with the separation phenomena that occur on the shock-generator plate.

BIOTECHNOLOGY AND HUMAN RESEARCH

Advanced Concepts

Research continued on new methods of protecting man from the lunar environment during extravehicular activities. Suits with chambers or free volume into which man can introduce his whole body or just the upper part were investigated. In such a suit, small airlocks would permit surface samples and equipment to be passed to the interior for examination or repair, or there might be arms, legs, and remote manipulators.

Biotechnology

Progress was made in research on the problem of providing an improved breathing atmosphere for spacecraft so as to enable man to remain in space longer. Two-gas sensor systems for controlling the needed two-gas atmospheres will permit upgrading present systems to provide an oxygen-nitrogen atmosphere. One such system being developed uses infrared and ultraviolet radiation sources and a total pressure sensor to identify the amounts of carbon dioxide, water vapor, oxygen, and nitrogen in the environment; it is scheduled to be delivered for test late in 1967. (Fig. 4–19.)

A technique (dielectrophoresis) which employs electric fields and the dielectric nature of materials was being studied for use in expelling subcritical fluids from storage containers in space.

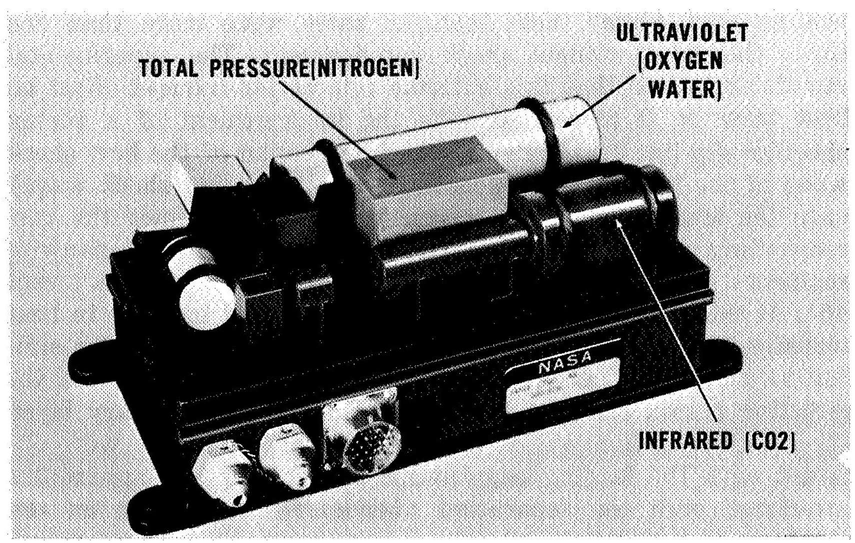


Figure 4–19. A two-gas system sensor.

Early tests indicated that adequate forces can be exerted on liquids to maintain their orientation in the weightless state, even against the vehicle stabilization forces. From the positive test results it appears that this technique may also be useful in locating fluids within containers to permit their withdrawal as either a gas or a liquid.

Human Research

Radiobiology research concentrated on the biological effects of protons, the predominant ionizing particles found in space. One study, at the U.S. Air Force School of Aerospace Medicine, was concerned with the effects on primates of various discrete proton energies found in solar flares. At Langley, an investigator used the cyclotron to study cataract formation on the lens of a rabbit's eye as a result of exposure to protracted low level proton radiation.

At Ames Research Center, respiratory studies were conducted on small animals (rats, rabbits, and dogs) in specially constructed chambers under controlled atmospheric conditions. It was found that prolonged exposure to increased pressures of pure oxygen will produce a condition in a rat's lung similar to emphysema in man. This finding may be useful in research on human emphysema which has been hampered by the inability of investigators to induce the disease in laboratory animals.

In studying the effects of launch accelerations on the respiratory exchange of gases in the lung, an investigator found that the major lack of oxygenation (arterialvenous shunting) occurs in the collapsed, or atelectic, areas of the dependent portions of the lungs.

Man-Systems Integration

Research on extravehicular technology at Langley included pioneer studies in weightlessness simulated by neutral buoyance in water, and work on the design of airlock sizes and hatches, on the application of force and torque by the astronaut while weightless, and on astronaut rescue operations through hatches and airlocks. In September and October, several astronauts used contractor facilities for efforts to simulate the extravehicular activities (EVA) involved in the Gemini IX, X, XI, and XII flights. Astronaut Cernan wore his pressurized Gemini space suit underwater, performing portions of his Gemini IX EVA sequence while neutrally buoyant to review the difficulties he experienced in flight. Astronaut Aldrin rehearsed and modified the EVA procedures he proposed to use for Gemini XII (November 11–15). Following the EVA of the flight, he returned to the

underwater facility to reevaluate the EVA in simulation. Underwater simulation studies were also used to confirm the revised design of astronaut footholds in the Gemini adapter and have been effectively applied to developing procedures and to human factors design.

CHEMICAL PROPULSION SYSTEMS

Solid Propulsion Research and Technology

Rocket nozzle gas dynamics studies were conducted at the Jet Propulsion Laboratory using a newly developed gas flow test facility, the Auxiliary Flow Channel. The channel receives its air from the air supply pipe of the continuous flow hypersonic wind tunnel. The stagnation chamber, test nozzle, and diffuser, are adjacent to the tunnel and reconnect into its diffuser. In flexibility of operations, range of operating characteristics, and quality of data the Auxiliary Flow Channel surpassed expectations.

Research in combustion instability, carried out by the Naval Ordnance Test Station (NOTS) with NASA funds, contributed to scientific understanding of the phenomenon, advanced experimental methods, and produced practical results directly applicable by propulsion engineers.

Lewis Research Center contracted for the development and demonstration of an integral combustible mandrel for solid propellant rocket motors. This work is intended to provide a technically and economically feasible alternative to casting rocket motor grains around solid metal mandrels. Such a system would offer advantages in handling and interior ballistics as well as such benefits as: grain support during storage; a hermetic seal protecting propellant from vacuum environment; improved ignition of complex grain shapes; and highly complex grain geometrics.

Research conducted for NASA at a number of universities has produced such valuable results as improved beryllium metal combustion efficiency, data on ignition and steady-state combustion, and important information on stress analysis and failure criteria in propellant viscoelastic behavior. The university effort in propellant structural integrity, which has helped assure solid motor structural integrity, is collated with related work at JPL.

Solid Propulsion Experimental Engineering Program

Substantial progress was made toward the firing of the third 260-inch-diameter motor. Designed to develop a maximum thrust of 5.4 million pounds and burn approximately 70 seconds, it was

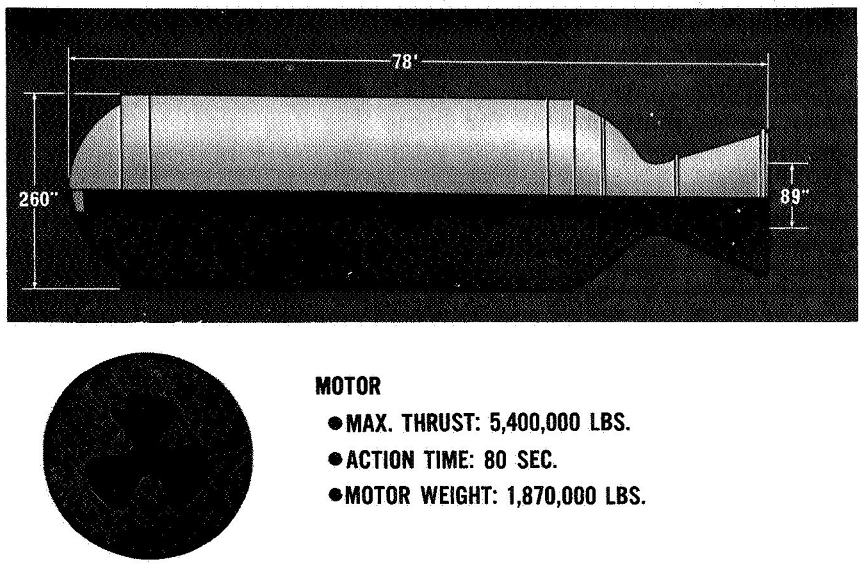


Figure 4–20. Large solid motor design.

scheduled to be tested in June 1967. A previously used motor case was selected, completely reinspected by X-ray and ultrasonics, and pressure tested successfully in the firing pit at the contractor's plant. The reusable thick insulation inside the end domes of the motor case was cleaned up, and new insulation was applied along the cylindrical length of the case. (Fig. 4–20.)

A process for fabricating the inert slivers, which will be used in the 260-inch motor to control the rate of thrust tail-off at the end of burning, was developed, and 3 full-length slivers were manufactured and bonded internally to the motor. A propellant development program resulted in the 50 percent increase in burning rate required for the additional thrust. The full scale mixing equipment underwent 4 trial runs in efforts to perfect propellant composition, viscosity, and cure time. Also, a steel nozzle shell was modified so that although it will not be movable, the nozzle will simulate a steerable nozzle configuration. Finally, tape wrapping and curing of the half-dozen ablative nozzle sections was well underway at the contractor's plant.

In supporting technology, propellant was cast in a 44-inch diameter motor which will reproduce to scale the propellant design and nozzle configuration to be used in the third 260-inch motor test. The scale model will be used to investigate flow conditions around the submerged throat for comparison between real and predicted erosion data. Another program, which investigated a low nickel alloy steel (HY–150) for use in large motor cases,

also made progress. The steel demonstrated remarkable toughness or "tear resistance" in a series of tests, a preformed crack reducing the burst strength of the test vessel by only 8 percent. The ability to withstand defects could increase case reliability and reduce requirements for inspecting and repairing the welds in large motor cases, and, in addition, lower material costs and fewer manufacturing operations offer a potential economic advantage.

A NASA committee was established to evaluate studies of solid and hybrid motors for possible applications in future NASA launch vehicles and to recommend a system for prototype development. Candidates systems included high energy conventional designs, pulse motors generating a series of preplanned thrust increments, high energy hybrid systems, and variable thrust motors controlled by fluid injection into the chamber or by varying the throat size.

Liquid Propulsion Research and Technology

Space Storable Propellants.—Progress was made in the technology of these propellants as investigators obtained high measured performance (later confirmed by new thermodynamic calculations) with the oxygen difluoride-diborane system at low chamber pressure without the damage to hardware experienced in earlier tests. As a result, plans were made to broaden research efforts in this area.

Tripropellants.—Early results of a program to evaluate the lithium-hydrogen-fluorine ($Li\text{-}H_2\text{-}F_2$) propellant combination indicated the feasibility of this very high performance propellant system. Based on the liberation of a large amount of heat by burning the lithium with the fluorine, then transferring that heat to the gaseous hydrogen, the system is relatively insensitive to the proportions of the three liquids, so long as there is enough fluorine to react with all the lithium. Thus, it appears that three propellant tanks can be emptied simultaneously, that attainable lithium droplet sizes will burn in a reasonably sized chamber, and that the heat transfer problems are not insoluble.

Liquid Propulsion Experimental Engineering Programs

Launch Vehicles.—In the final phases of the M–1 engine phaseout program, the performance and stability of the combustion chamber were determined in a short series of tests. The tests (Fig. 4–21) provided valuable data which can be used as an upper anchor point for scaling laws, thereby eliminating a number of steps from injector design procedures. Tests were conducted on a new liquid hydrogen pump design which de-

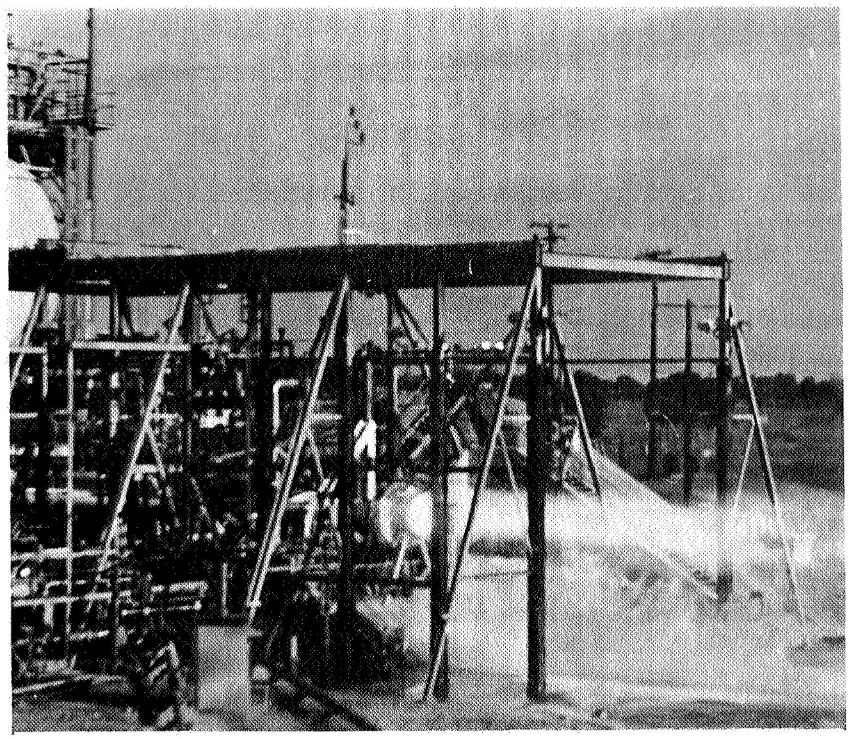


Figure 4–21. M–1 engine test firing.

livered over 5000 psi discharge pressure—more than twice that previously obtained—and first tests of a companion liquid oxygen pump capable of comparable pressures were satisfactory. The two pumps will provide propellant to a high pressure engine superior to current designs. Finally, in a program to investigate the dynamics, start transients, and operating problems of a toroidal aerospike engine, a multiple inlet liquid oxygen manifold was fabricated; in test of flow distribution and filling characteristics, it proved very satisfactory. (Fig. 4–22.)

Space Propulsion.—A 1000-pound internally cooled beryllium chamber successfully completed almost one hour of tests, using earth storable propellants. This design concept is being considered for application to Voyager, and testing will be continued to establish steady state and transient operating limits and throttling characteristics. (Fig. 4–23.)

A number of test programs made worthwhile progress: A low chamber-pressure FLOX-LPG (Liquified Petroleum Gas) thrust chamber underwent about 2 dozen tests, providing data which will help establish the operating characteristics of this

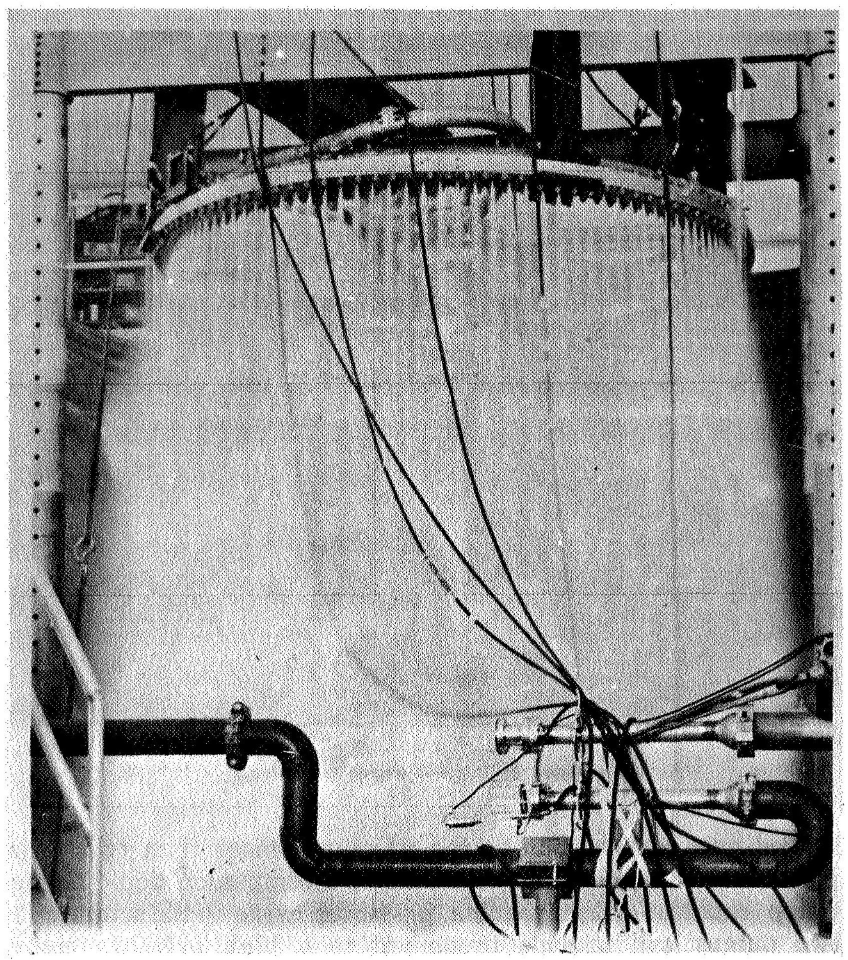


Figure 4–22. Manifold water flow test.

class of engines. Two 30-minute tests were successfully completed on modified LOX pumps with 82 percent FLOX; this work advanced the testing of a FLOX-Methane RL–10 A–1 engine. Also, additional data on kinetic losses of the fluorine-hydrogen propellant combination were obtained in altitude tests of a 1250-pound-thrust, 60-to-1-nozzle-area-ratio thrust chamber operating at 50 psia chamber pressure. And tests were begun on a tank shut off valve and a vent and relief valve designed for liquid fluorine to confirm design criteria.

Auxiliary Propulsion.—In studying a new concept for reaction control rockets using hydrogen and oxygen as propellants, catalytically ignited heat exchangers and thrusters were tested

and combined in a complete system. The results indicated good possibilities for integrating the concept into the high energy launch vehicles and spacecraft using cryogenic propellants.

BASIC RESEARCH

Fluid Physics

Measurements were made of the transition from laminar to turbulent boundary layer flow on small models at speeds up to 15,000 mph. Preliminary results indicate that laminar boundary layers, which minimize total heat transfer to the body, can be maintained on ablating cones at conditions corresponding to re-entry from interplanetary flight. At these speeds it is essential to have a laminar boundary layer functioning so as not to exceed the capacity of the heat shield system. This research is particularly significant because it provided accurate measurements of the effects of ablation on transition for the first time.

In the flow around a vehicle at hypersonic velocities, the temperature in the gas changes rapidly, increasing in passing through shock waves and decreasing in the expansion regions. Accurate prediction of aerodynamic and heat transfer characteristics is important in vehicle design, but several investigations revealed that theory was inadequate for this purpose. Consequently, meas-

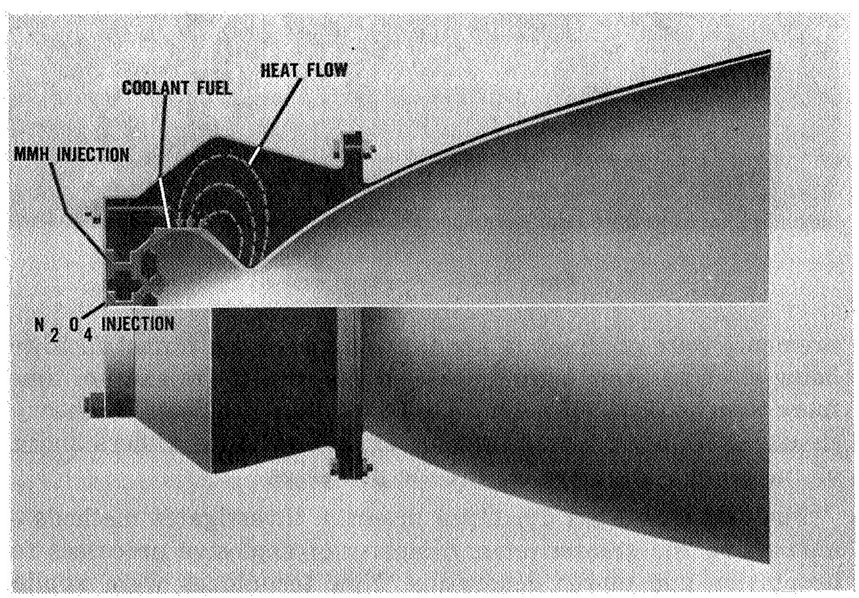


Figure 4–23a. Beryllium thrust chamber.

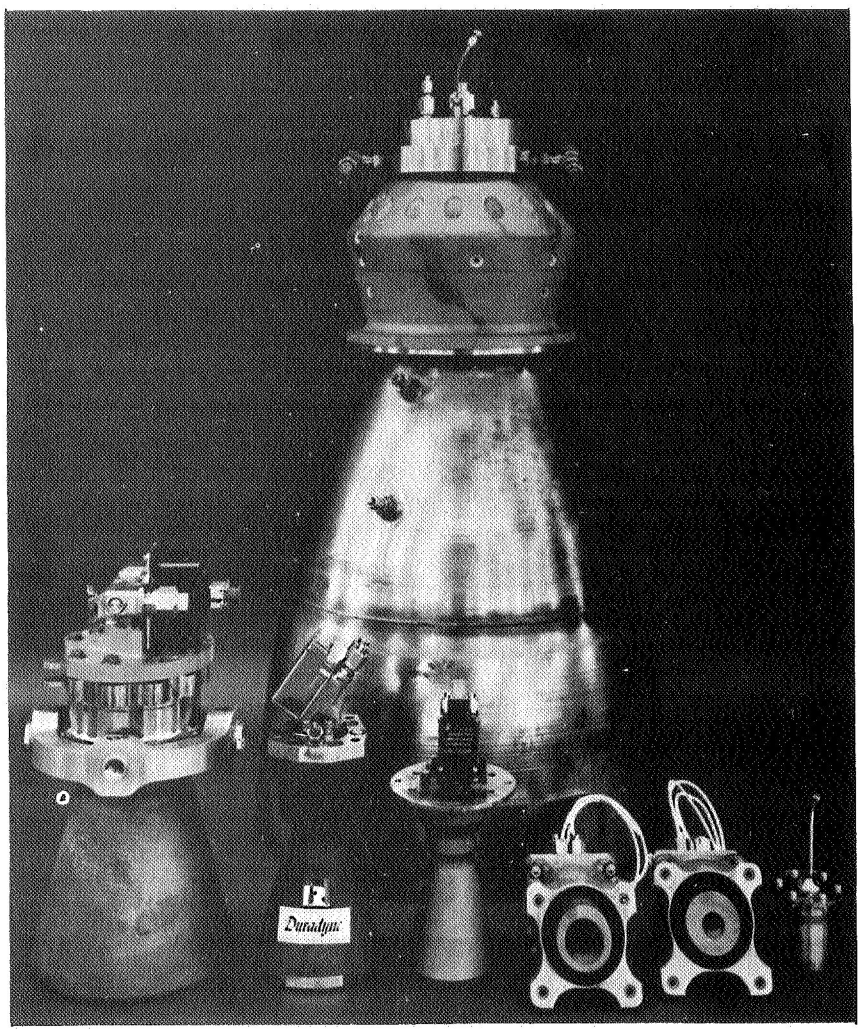


Figure 4–23b. Beryllium engine.

urements were obtained in arc tunnels and shock tunnel facilities using electron beam techniques, and the results (relaxation times more than an order of magnitude faster than predicted by theory) should establish adequate rate data and enhance understanding of the underlying chemical kinetic processes.

The detonation gas dynamics program investigates methods of harnessing the greater energy density of explosive processes for propulsion and power generation. New techniques were applied in studying explosive gas mixture detonations to enlarge understanding of these extremely fast and complex physical and chem-

ical processes. Schlieren photographs obtained by using a laser stroboscope showed clearly, for the first time, the beginning of detonation in hydrocarbon-oxygen mixtures and the subsequent shock wave propagation within a combustion tube.

Applied Mathematics

Mathematicians at Marshall Space Flight Center developed a new autoprogrammer called AMTRAN based on a new concept in computer technique—time sharing from remote terminals. In this computer system, several AMTRAN terminals will be linked to a central electronic digital computer. The AMTRAN terminal, located near the user, consists of a keyboard, typewriter, or graphic displays on the oscilloscope. Most of the non-numerical programming as well as the numerical analytical work is done automatically by the computer itself rather than by the usual human programmer. Tests indicated that this new computer system may reduce the time required for solutions of certain problems by factors of 100 or more.

Materials

Research continued on solid lubricating compounds such as graphite, molybdenum disulfide, and calcium fluoride, whose crystalline structure consists of layers of atoms which slide easily over one another. Such compounds can withstand heat without evaporating or decomposing, but they are limited to intermittent or short-life applications because they are eventually wiped off the surface they protect, and secondly, they keep their lubricity (slippery characteristic) over a limited range of temperature. In recent work, ball-bearing cages were machined from porous metal and then impregnated with a molten calcium fluoride-barium fluoride mixture. This method provides a reservoir of solid lubricant and greatly extends its lifetime. A typical ball-bearing containing such a composite lubricant was operated at 1200°F (about 500° above the temperature limit of the best liquid lubricant) for nearly 1000 hours without failure. This time compares with perhaps 10 hours of life for the same lubricants applied as a single film. Progress was also made in increasing the effective temperature range. A fluoride mixture, for example, lubricates between 500°F and 1500°F but is not effective at lower temperatures. Incorporating finely powdered silver into the coating formulation gave a lubricant effective over the full range from room temperature to 1500° F.

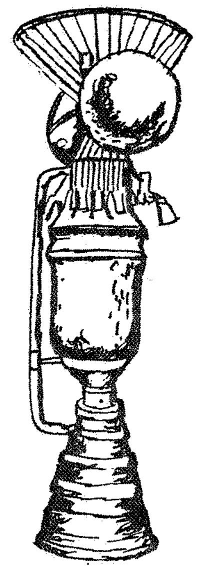
Ames Research Center studies of the mechanical properties of polymers resulted in a damping mechanism design concept more efficient than existing dampers by an order of magnitude. This

concept uses polymeric materials at temperatures over a range of 10° to 50°C or more where configurational rearrangements of the polymer chain backbones allow very high mechanical energy absorption and increased damping. Several thermoplastic materials, including polymethylmethacrylate, were tested, and development work continued to bring the concept to the engineering stage.

Electrophysics

At Ames, research was underway to determine whether electrical rather than thermodynamic forces are responsible for the very high angular momentum and consequent destructive force of tornado clouds. The usual (thermodynamic) explanation is that the funnel cloud results from the condensation of moisture and a lifting of air in the vortex. In the current research, the premise is that the presence of two unlike electrically charged atmospheric regions establishes a large electric force field. The space between the regions is filled with positively and negatively charged water droplets. The electric field exerts a force which causes the negatively charged droplets to move to the positively charged region, and the positively charged droplets to move to the negatively charged region. In this way, circulation starts and is maintained because of the electrostatic repulsion and attraction of the charged water droplets and the respective charged cloud regions. The theory was supported by a laboratory experiment. In the test, steam droplets, electrically charged and accelerated as they came under the influence of alternately-charged, spaced electrodes, showed a net rotary motion. A model closely approximating the tornado was being developed so that the electrical energy transfer within the tornado and the many factors which affect vortex formation can be determined.

The research indicated that it might be possible to eliminate tornadoes by firing a fine wire through the charged atmospheric regions to trigger an electric discharge, thus dissipating the stored electrical energy and preventing a circulatory buildup of the water droplets.



5 NUCLEAR PROPULSION AND POWER GENERATION

NASA continued to achieve significant results in the nuclear rocket program, the SNAP-8 development project, the electric propulsion program, and the solar and chemical power research and technology efforts.

THE NUCLEAR ROCKET PROGRAM

The major objective of the joint NASA/AEC nuclear rocket program is to provide the rocket propulsion technology and systems for conducting high-energy, heavy-payload missions beyond Apollo. Mission application studies have shown that nuclear rockets can provide a versatile propulsion capability that can benefit the space program for some years to come. Tests conducted under the nuclear rocket program have demonstrated the high performance of these systems. They have also provided the confidence necessary to include nuclear propulsion in planning future space activities.

Graphite Reactors and Engine Systems

The nuclear rocket program continued to concentrate on developing graphite reactor and engine system technology. During the second half of 1966, the specific objectives were to further the development effort aimed at increasing the corrosion lifetime of the reactor, to move forward with the development of advanced

graphite reactor technology aimed at providing the basis for extending reactor performance, and to continue establishing the engine system technology based on the use of the 1100 megawatt reactor technology.

The maximum time a reactor can be operated at full power depends on how well the graphite in the reactor (fuel elements, etc.) resists corrosion by the hydrogen propellant. Mission application studies for the advanced space missions now being considered call for a full power operating time of 20 to 40 minutes. The goal in the reactor technology program is to achieve the ability to operate a reactor at full design conditions for 60 minutes. This will enable NASA to meet the mission requirements with a reasonable operating margin and permit effective use of hardware in engine development tests.

During the first half of 1966, two reactors were carried to full design conditions (as reported in the *15th Semiannual Report*, ch. 5). The data from these experiments and laboratory tests of critical reactor components indicated that the full-power operating times called for by mission application studies were within reach. Development testing of the NRX–A6 (NRX—NERVA Reactor Experiment) reactor became the next planned step to further the progress in this direction.

Researchers conducted a fuel assessment program to provide a revised specification for a fuel element that would extend the full-power operating time of the NRX–A6 reactor. This program was completed with favorable results, and fuel element production was in progress. The fabrication of all other NRX–A6 hardware was also well underway.

As work continued to improve the corrosion resistance of the reactor to extend reactor lifetime, work also progressed at AEC's Los Alamos Scientific Laboratory on the Phoebus graphite reactor technology. The objective is to improve the KIWI/NRX technology to meet the requirements of the large, high-power Phoebus 2 design. KIWI-sized reactors, designated Phoebus 1, were being used to evaluate new hardware designs and innovations planned for incorporation in the larger Phoebus 2. The Phoebus 2 reactor is expected to have a power of between 4000 and 5000 megawatts, and an altitude thrust equivalent of between 200,000 and 250,000 pounds.

During this report period, assembly of the second in the series of Phoebus 1 reactors, the Phoebus 1–B, was completed at the Nuclear Rocket Development Station (NRDS). (The 1–B was moved to Test Cell "C" on January 7, 1967, and was being readied for testing.) In addition, assembly of the first Phoebus 2 reactor, the Phoebus 2 Cold-Flow, was initiated in the Reactor Mainte-

nance Assembly and Disassembly building at NRDS. Meanwhile, the assembly of the Phoebus 2A reactor core for reactor criticality experiments was begun at Los Alamos. Following the critical experiments at Los Alamos, the core is to be disassembled and shipped to NRDS for assembly with other Phoebus 2A reactor components.

Having these two Phoebus 2 reactors in various stages of assembly represents the culmination of complex fabrication and manufacturing development efforts, including work on fuel elements. Thousands of fuel elements were fabricated. Although those of the Phoebus 2 Cold-Flow reactor contained no fissionable material, those of the Phoebus-2A reactor had to be precisely loaded with uranium according to their location in the reactor.

Significant progress was also made in high temperature materials technology. Los Alamos scientists, in association with other program participants, produced composite materials consisting of machinable graphite and metal carbide mixtures which exhibited a high degree of corrosion resistance. These materials also exhibited a sufficient high-temperature strength to serve as structural materials in a reactor core.

Further significant steps were taken to develop high-temperature thermocouples for placement in reactors. Several of these new thermocouples and exit gas temperature sensors were made available in time for installation and evaluation in the Phoebus 1-B reactor. If these work well, reactor developers should have an improved means for monitoring the temperatures within the reactor during test operations.

Another major program effort supporting reactor development is the work being conducted by a contractor on the exhaust nozzle for the Phoebus 2 reactor. The design of the Phoebus 2 nozzle is similar to that of the U-tube nozzle used for NRX-A reactor testing. However, it is larger and is fabricated from Hastelloy X instead of stainless steel to accommodate the higher temperatures and heat fluxes.

Earlier in 1966, the Phoebus 2 nozzle development test stand was activated, using an uncooled nozzle; this was a five-second duration test to qualify the stand only. During this report period, fabrication of the first cooled nozzle for development testing was completed. This nozzle was being hydrotested. If all goes well in the repair of expected minor leaks, it will be used in a 75-second demonstration test later in 1967 to establish nozzle development status and to provide the basis for further improvements.

The first power tests in the engine system technology program were conducted, using the NRX/EST (EST—Engine System Test). The NRX/EST was designed to permit the evaluation of

the "hot-bleed" cycle of engine operation and the phenomena associated with engine "bootstrap" startup (engine starts as a self-contained unit with no external energy assistance). The NRX/EST also was a "breadboard" system: it contained all of the components of a flight type engine with no attempt being made to arrange these components as they would be in a flight system. (A complete engine description appears in the *15th Semiannual Report to Congress.*)

The XE (experimental engine) engine will closely resemble a flight configuration. The objectives of the XE program will be to explore further the phenomena associated with engine startup, to obtain data on the shutdown and cooldown of the engine using the liquid hydrogen propellant, and to acquire further data on engine system interactions and control under simulated altitude conditions. An additional and very important objective will be to gain experience in operating the XE engine and Engine Test Stand No. 1 as a system.

The current ground experimental engine program provides for the testing of one cold flow engine, called the XECF, and two power engines, called the XE–1 and XE–2. The XECF will be used primarily to check out and activate Engine Test Stand No. 1 which is now in the final stages of completion.

During the period covered by this report, all of the major components for the XECF and XE–1 engines were fabricated. The non-reactor engine components were being assembled at the end of the period, as was the XE–1 reactor core (the latter at a contractor's facility). The fabrication of XE–2 components also was initiated.

Facilities

Facilities under construction or modification at the Nuclear Rocket Development Station in Nevada included Test Cell "C," Engine Test Stand No. 1, and an Engine Maintenance, Assembly, and Disassembly Building, called E–MAD.

Test Cell "C" was modified during 1965–66 for testing of the higher powered Phoebus and NRX series of reactors. The major improvements were the addition of a one-million gallon liquid hydrogen storage dewar, an emergency pressurized liquid hydrogen storage dewar for supplying hydrogen coolant to a reactor in the event of a feed system failure, and a high capacity feed system—the NFS–3b. With these modifications, Test Cell "C" became the principal reactor test facility at NRDS.

Development of the NFS–3b feed system was still in progress at period's end. The system consists of two pump-turbine units connected in parallel and is designed specifically to meet the

pressure and flow requirements for Phoebus 2 reactor testing. A second and unique design feature of the system is that it can be operated with only one pump turbine unit (single barrel). Such a system was installed in Test Cell "C" to accommodate the testing of the KIWI-sized Phoebus 1–B reactor.

During this report period, a single barrel NFS–3b was installed at Test Cell "C" and checked out at 30,000 rpm for 45 minutes. The disassembly and inspection of this unit following the test showed all components to be in excellent condition. The conditions under which the unit was checked out exceeded the pressure and flow requirements for Phoebus 1–B testing.

Engine Test Stand No. 1, which will be used for the ground experimental engine (XE) test program, was brought close to completion. The engine exhaust duct was installed and hydrotested, and installation of the engine shields was initiated. Both items are components of the test stand's exhaust and altitude simulation system.

In the E–MAD building, the major activity was directed toward installing and checking out both the building equipment and the equipment items required for remotely servicing and examining radioactive reactor and engine system components. The building is scheduled to be completed and activated for use by mid-1967.

Isotopic Thruster Propulsion Systems

Another form of propulsion being investigated under the Nuclear Rocket Program involves the use of radioisotopes as the source of thermal energy. NASA, the Air Force, and the AEC are jointly conducting radioisotope thruster programs.

Isotopic thrusters use the thermal energy produced by the decay of an encapsulated radioisotope to heat a propellant. The propellant is then exhausted through a rocket nozzle to produce thrust. These thrusters can provide relatively low thrusts (one-millionth to one-tenth of a pound) at high specific impulses (200–800 sec., depending on propellant and radioisotope-fueled capsule temperature capability).

Two classes of radioisotope-heated thrusters were under investigation in 1966. One was a relatively high-thrust, high-performance, short-lived thruster suitable for primary stage propulsion applications. Such a thruster requires the use of hydrogen as a propellant, a capsule temperature greater than 3600°F, and a radioisotope thermal power in the range of 15 kw. The thrust level is about one quarter of a pound. Subsequent to the cooperative Air Force-AEC limited ground test of this class of thruster in February 1965, the AEC continued supporting programs aimed

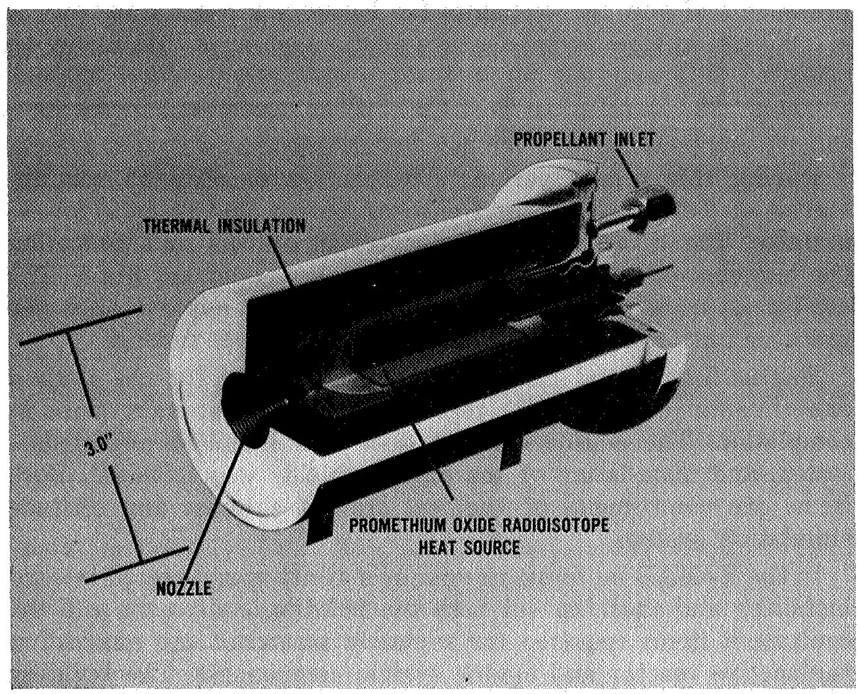


Figure 5–1 Promethium fueled thruster.

primarily at establishing the radioisotope fuel form and capsule technology necessary for this high temperature service.

The second class investigated included lower thrust, moderate performance, long-lived thrusters suitable for spacecraft attitude control functions. These thrusters, using ammonia as a propellant and near-at-hand 2000°F capsule technology, can provide specific impulses in the range of 250 seconds with thrust levels of from ten thousandths to one hundred thousandths of a pound for thruster weights on the order of three pounds. Furthermore, these thrusters are simple, low pressure, monopropellant systems requiring no external power or thermal controls. While no specific system requirements have yet been identified, both the NASA Goddard Space Flight Center and the Air Force Rocket Propulsion Laboratory have established cooperative programs with the AEC which include ground tests of radioisotope fueled thrusters. Goddard's promethium fueled thruster (Fig. 5–1) completed a one month test program at the AEC's thruster test facility at the Mound Laboratory in early December 1966, and the Air Force's plutonium fueled thruster is scheduled for testing in January 1967.

THE SNAP–8 DEVELOPMENT PROJECT

During this period, the contractor completed his restaffing to meet the needs for continuing the development of SNAP–8. Also, the program was reoriented to place priority on solving boiler and turbine problems revealed by the test of the breadboarded power conversion system. Corrective designs and supporting experimentation were started. Additional test facilities were being activated to provide for increased component testing.

NUCLEAR ELECTRIC POWER RESEARCH AND TECHNOLOGY

Nuclear electric power research and technology work continued in four broad areas—Rankine turbogenerator technology, thermionic conversion technology, low power Brayton cycle equipment, and isotope power.

Rankine Turbogenerator Technology

The two-stage potassium vapor turbine at the contractor's plant, operating with slightly wet vapor, successfully completed a 5000-hr. endurance test without evidence of impact erosion or mechanical damage of the turbine blades. Also, the design of a three-stage turbine was completed.

This three-stage turbine is intended, specifically, to investigate turbine operation with high vapor "wetness" values. The rotor disks of two stages of the turbine will be constructed of an advanced molybdenum-base alloy. A provision for removing turbine blades will allow testing of various advanced refractory alloy blade materials. Direct comparison of their corrosion and erosion resistance will be possible.

A 2100°F boiling potassium corrosion loop, built of a refractory metal alloy (Cb–1Zr), successfully completed a 5000-hr. endurance test with negligible evidence of corrosion. Fabrication was started on a similar potassium corrosion loop having duct walls made of an advanced refractory tantalum-base alloy (T–111). The corrosion resistance of T–111 to boiling and condensing potassium at temperatures up to 2150°F will be tested in this loop.

Thermionic Conversion Technology

The thermionic conversion program continued to emphasize work related to the technology needed for the construction of the thermionic "in-core" reactor system. Important test data were obtained on system materials problems, particularly those concerning the effects of reactor radiation and high temperatures upon the electrical and thermal properties of electrical insula-

tors, and those concerning the combined effects of high temperatures and long time periods upon the metallurgical characteristics of emitters and reactor fuels both separately and when the fuels and emitters are in contact.

Test data indicated that the use of emitter metals with specially oriented crystal structures will provide the same thermionic performance at considerably lower temperatures than would those with the conventional "disordered" structure emitters. Tests were being performed to determine if such metal structures, once established, would remain unchanged for the long periods required at the high operating temperatures, under irradiation and under stress.

Low Power Brayton Cycle Equipment

The current Brayton cycle technology program is aimed at demonstrating high component and subsystem performance in small-

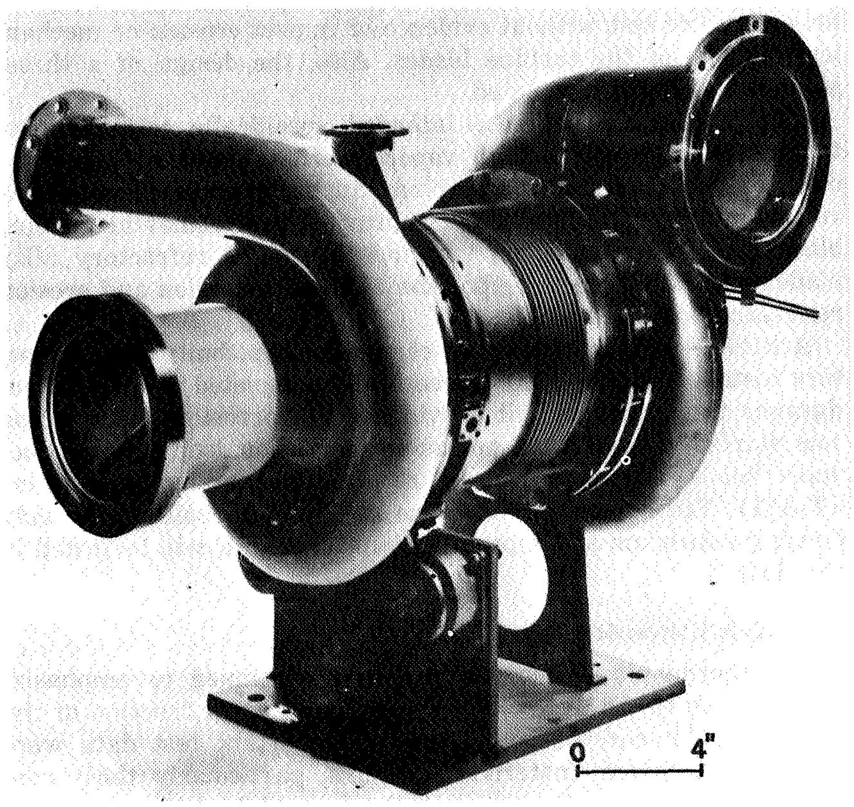


Figure 5–2. Turbo compressor for Brayton gas turbine cycle.

sized units typical of those that would be used with radioisotope heat sources.

"Cold" flow performance tests were essentially completed at NASA-Lewis on 6-inch diameter radial flow turbine and compressor research components. The "hot" flow tests on the gas bearing-equipped radial turbo-compressor package which began in February, 1966, were continuing. (Fig. 5–2.) Open loop testing of this package, using an argon gas working fluid, achieved stable bearing operation at the design rotating speed for turbine-inlet temperatures up to 1200°F. A higher turbine inlet operating temperature up to 1500° F is the goal of the present testing. A test program investigating start-up and shut-down procedures will follow.

Design work began on the components (compressor, turbine, alternator) of a smaller, single-shaft power unit sized to deliver 5.5 electrical kw. Final design of this unit should be completed in March 1967.

Isotope Power

A contractor continued conducting investigations to determine the usefulness of heat pipes with isotope heat sources operating at temperatures exceeding 1400°C. A high temperature heat pipe (1500°C) has been running for over 7000 hrs., and it is planned

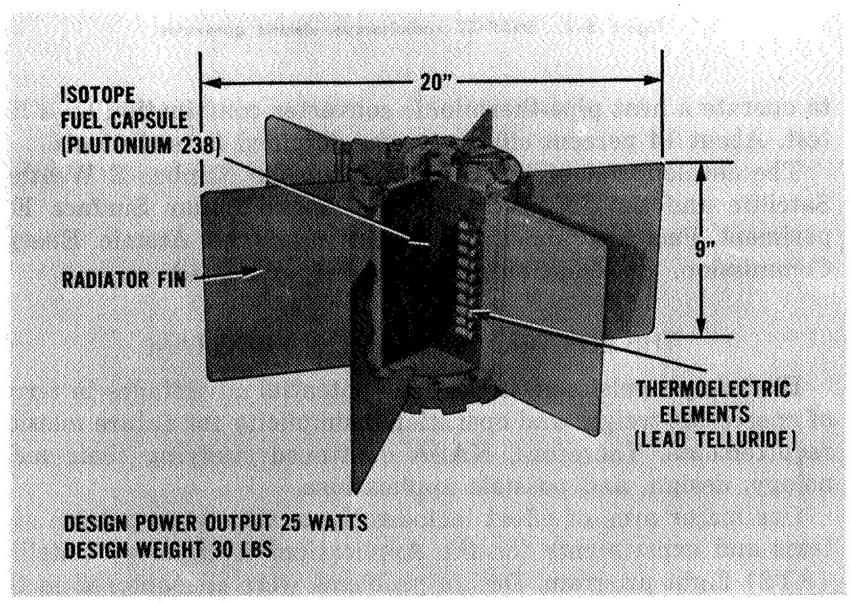


Figure 5–3. SNAP–19 radioisotope electric generator.

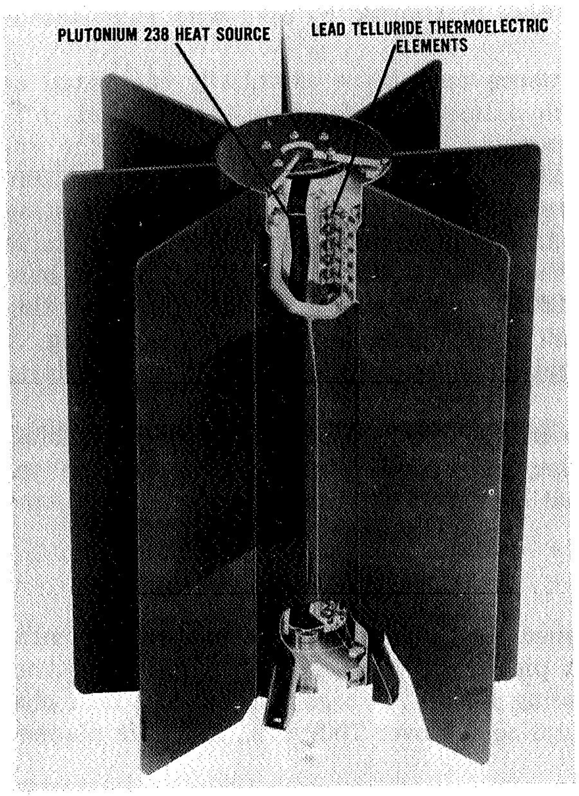


Figure 5–4. SNAP–27 radioisotope electric generator.

to operate a heat pipe-thermionic converter combination on a life test. About 14 percent efficiency was obtained in early tests.

The development of the SNAP–19 for the Nimbus-B Weather Satellite and the SNAP–27 for the Apollo Lunar Surface Experiment Package, under the direction of the Atomic Energy Commission, was continuing. (Fig. 5–3 and 5–4.)

THE ELECTRIC PROPULSION PROGRAM

Electric propulsion systems offer potential advantages in terms of spacecraft weight and operational simplicity for future mission requirements. Therefore, NASA continued studying their technology, design, and possible applications.

One major area of effort includes the auxiliary propulsion systems and experiments for the Applications Technology Satellite (ATS) flight program. Design problems were encountered in the development of the small ion engine intended for use on the ATS–B. A very low thrust resistojet was integrated with the

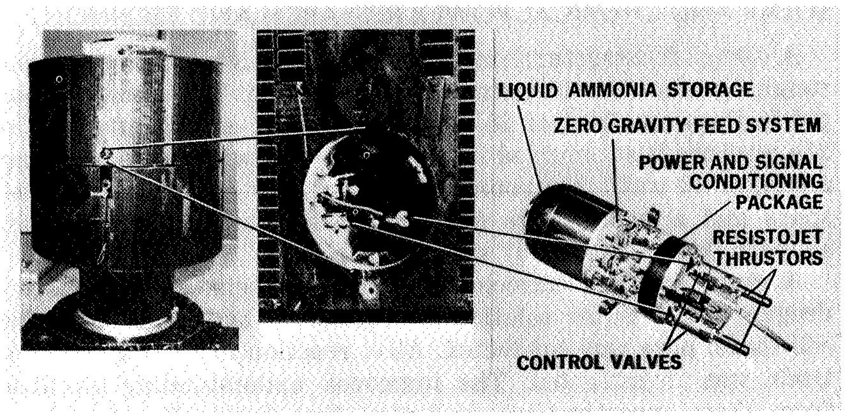


Figure 5–5. Resistojet experiment on ATS–I.

ATS–I spacecraft in place of the ion engine and launched on December 6, 1966. (Fig. 5–5.) (Initial experiments with this system began in January 1967.) A further experiment with a resistojet at a lower thrust level was also being planned for the ATS–C spacecraft. If satisfactory performance is achieved on this latter flight, the ATS–D&E spacecraft are expected to carry resistojets as operational East-West station-keeping systems.

Work on the ion engine continued under the direction of the Goddard Space Flight Center. Experiments are also being planned for the ATS–D&E spacecraft.

NASA continued to work on auxiliary propulsion for manned space station position control and on solar-powered prime or mid-course propulsion, with emphasis on system problems of the latter. A 500-hr. ion engine system test, including flight type power conditioning and controls, mercury electron–bombardment thrustor, and feed system was successfully carried out. Such systems show promise of increasing the payload capabilities of unmanned interplanetary spacecraft.

The most significant accomplishment during this period was the satisfactory endurance testing of a cesium bombardment ion engine. One such engine successfully completed 8189 hours of operation on November 1, 1966. The test was terminated at that point because of propellant exhaustion. Inspection of the electrodes subsequent to the test indicated that substantially greater life could reasonably be expected.

The successes with both the cesium and mercury electron-bombardment ion engines led to the decision to proceed with a long duration test in space under the SERT II program. This test is expected to take place in 1969.

SOLAR AND CHEMICAL POWER RESEARCH AND TECHNOLOGY

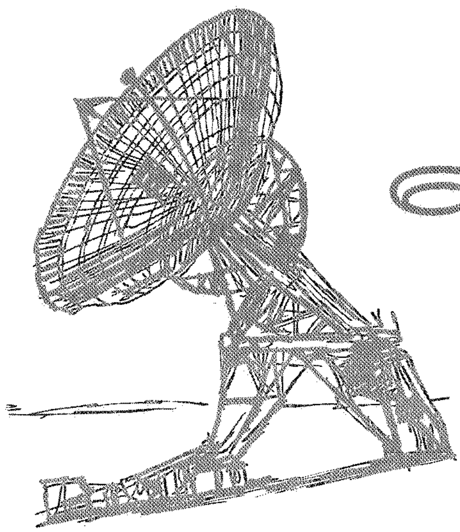
A 25 sq. ft. structural model of a lightweight solar cell panel weighing less than 10 pounds was completed. The electrical output is the equivalent of 25 watts per pound, an improvement of 2½ over the best obtained in the past. Work will continue toward a goal of 40 watts per pound, using biconvex (curved) beryllium spars and a hollow core electroformed aluminum substrate to support thin (0.004-inch) silicon solar cells.

A study of the electrochemical reaction between gaseous hydrogen and a water solution of potassium hydroxide in a fuel cell model pore was conducted. Also, reaction at the oxygen electrode was investigated. The improved understanding resulting from these investigations indicated that fuel cells of reduced size, weight, and cost should be possible.

The transfer of electrical power from an oriented solar array to the spacecraft in the presence of continuous rotational motion between the array and spacecraft presently involves the use of sliding electrical contact surfaces (slip rings and brushes). Such sliding surfaces are a potential limitation in achieving reliable spacecraft lifetimes of several years for various future missions such as application satellites.

A rotary power transformer which would transfer the electrical energy electromagnetically would eliminate the sliding electrical contacts and minimize any friction interactions between the array and spacecraft. Additionally, such a device could also provide the transformer functions normally required in the power conditioning subsystem.

Analysis, design, and fabrication of a prototype rotatable electrical power transformer for this type of application was satisfactorily completed. Performance evaluation in laboratory tests gave evidence that a suitably small, lightweight, and efficient rotary power transformer can be constructed.



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TRACKING AND DATA ACQUISITION

The NASA tracking networks supported 59 missions during this period. Thirty-two of these missions were launched before July 1, 1966. Some of the more important flights launched and supported currently were Gemini X, XI, and XII; Apollo/Uprated Saturn 203 and 202; Lunar Orbiter I and II; Pioneer VII; ESSA III; and ATS–I. One of the highlights occurred during the support of the Lunar Orbiter II mission. On November 28, 1966, the Goldstone tracking station received close-up photographs of the vast moon crater Copernicus.

Also of interest were the successful completion of the Gemini Program and the support of two Apollo unmanned missions. The most recent unmanned mission, AS–202, provided the Manned Space Flight Network the first opportunity to test the Apollo Unified S-band (USB) system under actual operating conditions.

In addition to the operational activity, the network augmentations for Apollo continued. New land stations became operational, instrumentation ships were being completed and sea trials commenced, delivery of range aircraft began, equipment was being installed, and personnel were being trained to operate and maintain the network facilities.

MANNED SPACE FLIGHT NETWORK

The Manned Space Flight Network (MSFN) successfully completed support of the Gemini program, the second phase of the Nation's manned space flight program. Throughout the entire

Gemini program, the Network provided high quality tracking and data acquisition support and played a vital role in the success of Gemini.

Originally established to support Project Mercury, the Network was augmented and reconfigured to support the Gemini flights. This major augmentation was begun in mid-1962, and the Network was operational for the first Gemini launch in April 1964. Similar to the transition from Mercury to Gemini, the Network was undergoing another augmentation to provide the support capability required for the Apollo program. This augmentation was initiated concurrently with the Gemini support operations and is now in its final phases.

When completed, the Network for Apollo will consist of (a) ten 30-foot diameter antenna stations located at Cape Kennedy; Bermuda; Antigua; Ascension; Canary Island; Carnarvon, Australia; Guam; Kauai, Hawaii; Guaymas, Mexico; and Corpus Christi, Texas; (b) three 85-foot diameter antenna stations located at Madrid, Spain; Canberra, Australia; and Goldstone, California; and (c) one transportable 30-foot diameter antenna station at Grand Bahama Island. In addition, five instrumentation ships (Fig. 6–1) and eight aircraft, operated by the Department of Defense, and three 85-foot diameter antenna stations of the Deep Space Network will provide support for Apollo.

Secondary support will be provided by the NASA station at Tananarive, Madagascar; and by Department of Defense stations

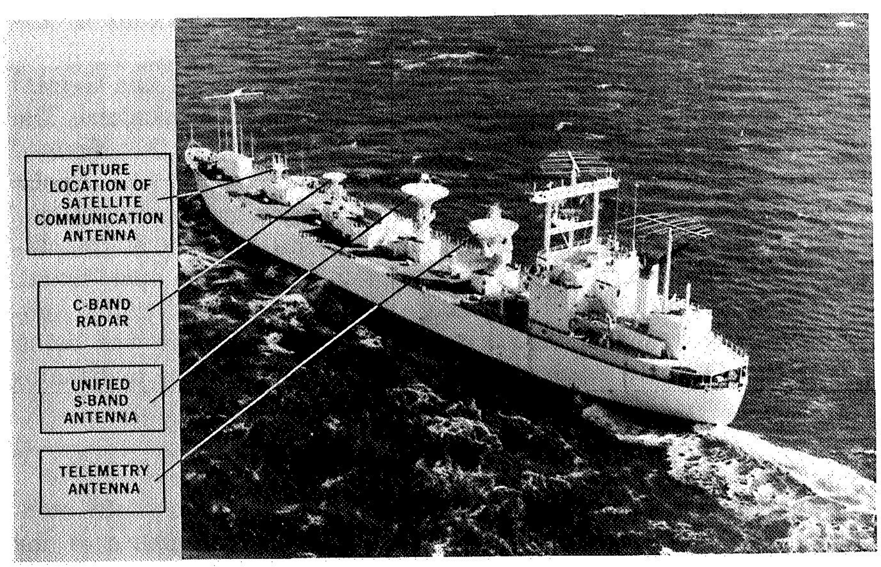

Figure 6–1. The USNS Vanguard undergoing sea trials.

at Point Arguello, California, and White Sands, New Mexico. It will be possible to provide the secondary support through existing Gemini equipment.

The conclusion of the Gemini program eliminated the requirement for the station located at Kano, Nigeria, and it was closed. Also, the support from the Department of Defense station at Eglin Air Force Base, Florida, was terminated. Current planning calls for two ships, the Rose Knot Victor and Coastal Sentry Quebec, to be phased out early in the Apollo Program.

Although still in the final stages of implementation, the Manned Space Flight Network's Apollo support facilities are already partially operational. The two unmanned Apollo Saturn missions launched during this period, AS–203 and AS–202, enabled the checkout of the support concepts (facilities, equipment, & operating procedures) being put into effect for Apollo. The AS–202 mission, in August, although primarily supported with Gemini systems, provided the network the first opportunity to test the Apollo USB system under actual operating conditions. The USB stations at Cape Kennedy, Bermuda, Ascension, and Carnarvon participated in the test. The operational qualification of the USB system is extremely important as all communications between the earth and the Apollo spacecraft will be transmitted through it.

DEEP SPACE NETWORK

The facilities of the Deep Space Network support NASA's unmanned flights to the moon and planets. The network continued supporting the Mariner IV and Pioneer VI missions, launched in 1964 and 1965, respectively, and increased its workload with support of 4 major missions launched during the period: Lunar Orbiters I and II, Surveyor II, and Pioneer VII. The network also provided launch and near-earth support for an Atlas-Centaur (AC–9) vehicle development test.

To provide continuous coverage of the unmanned lunar and planetary missions, the network stations are located in three general areas spaced at intervals of approximately 120° longitude around the earth. At the beginning of the report period, the network consisted of (a) operational 85-foot diameter antennas at Goldstone, California; Woomera and Canberra, Australia; Johannesburg, South Africa; and Madrid, Spain; (b) an operational 30-foot diameter antenna at Ascension Island; (c) a centralized control center (Space Flight Operations Facility, SFOF) at the Jet Propulsion Laboratory, Pasadena, California; and (d) a launch monitoring and final spacecraft-network compatibility checkout station at Cape Kennedy, Florida. Key im-

plementation effort during the current period included the completion of the second Madrid station and installation and completion of a third fully-interchangeable data processing system in the SFOF control center. These planned augmentations were carried out with minimum interruption of the support activity.

Perhaps the most publicized aspect of the network support was the receipt at the Goldstone station on November 23 of the close-up photographs of the vast moon crater Copernicus. One of these photographs was described as being among the greatest pictures of the century. The pictures had been taken five days earlier by the Lunar Orbiter II spacecraft and stored by the spacecraft until completion of the picture-taking phase of the mission. Upon commands from the SFOF, the pictures were processed on board the spacecraft and transmitted to the Goldstone station. During the highly successful Orbiter II mission, more than 4300 commands were transmitted to the spacecraft, and 411 photographs were received at the network stations.

SATELLITE NETWORK

The Satellite Network supports a wide variety of unmanned, earth-orbital scientific and applications satellites. This support must be able to satisfy the varying requirements of NASA, of other agencies, and of the international space programs since each flight mission has its unique support requirements and characteristics. For example, the Applications Technology Satellite (ATS) is positioned in a synchronous orbit and requires full time support—but only from a few selected stations. Conversely, the Orbiting Geophysical Observatory satellites do not require full time support from any one station, but, due to their orbital paths, require support from a greater number of stations for viewing periods varying from thirty minutes to two hours.

To meet these varied support requirements, the Satellite Network facilities have been developed over the past few years to provide a multi-mission general support capability, thus reducing the need to provide specialized facilities for individual flight programs. The network consists of electronic Space Tracking and Data Acquisition Network (STADAN) stations at 14 United States and foreign locations and a centralized control center at Goddard Space Flight Center, Greenbelt, Maryland. The STADAN stations are operated under the management of Goddard. The locations of the stations are as follows:

United States	*Foreign Countries*
Fairbanks, Alaska	Canberra, Australia
Goldstone, California	Carnarvon, Australia

United States	*Foreign Countries*
Fort Myers, Florida	Toowoomba, Australia
Rosman, North Carolina	Santiago, Chile
	Quito, Eduador
	Winkfield, England
	Tananarive, Madagascar
	St. John's, Newfoundland
	Lima, Peru
	Johannesburg, South Africa

The NASA STADAN stations are supplemented by Baker-Nunn and geodetic camera stations operated by the Smithsonian Astrophysical Observatory. This optical support is financed by a Research Grant from NASA to the Smithsonian Institution.

The STADAN supported 47 satellite programs during the period. Seventeen of these satellites were launched from July 1 through December 31, 1966, including the first Applications Technology Satellite (ATS–I) and the third in a series of operational meterology satellites (ESSA–III).

As part of a major effort in the Satellite Network to improve the use of existing station equipment, a Station Technical Operations Control (STOC) program was initiated. To meet the unique support requirements of each flight project, the general purpose station equipment—antennas, receivers, etc.,—must be rearranged between the different satellites passes. At present, a considerable amount of time is required for this equipment reconfiguration. The object of the STOC program is to reduce this set-up time and thereby make the equipment available for additional mission support. Central consoles were being designed and installed at network stations. These consoles make it easier to select and operate the stations' various equipment by reducing manual operation, centralizing the selection of needed equipment, and displaying station status to the console operator.

NASA COMMUNICATIONS SYSTEM

The NASA Communications System (NASCOM) is a network of operational communication lines and facilities which carry mission-related information in support of all NASA programs and the programs of other agencies as mutually agreed (Fig. 6–2). The NASCOM links, by teletype and voice/data circuits, over 100 locations, including 34 points overseas and encompassing over 600,000 route miles. The network consists of circuits provided by land lines, underseas cables, high frequency radio, and communications satellites.

The NASCOM, operated by the Goddard Space Flight Center, provides reliable worldwide communications between such facilities as the foreign and domestic tracking stations, instrumentation ships, launch areas, test sites, and mission control centers.

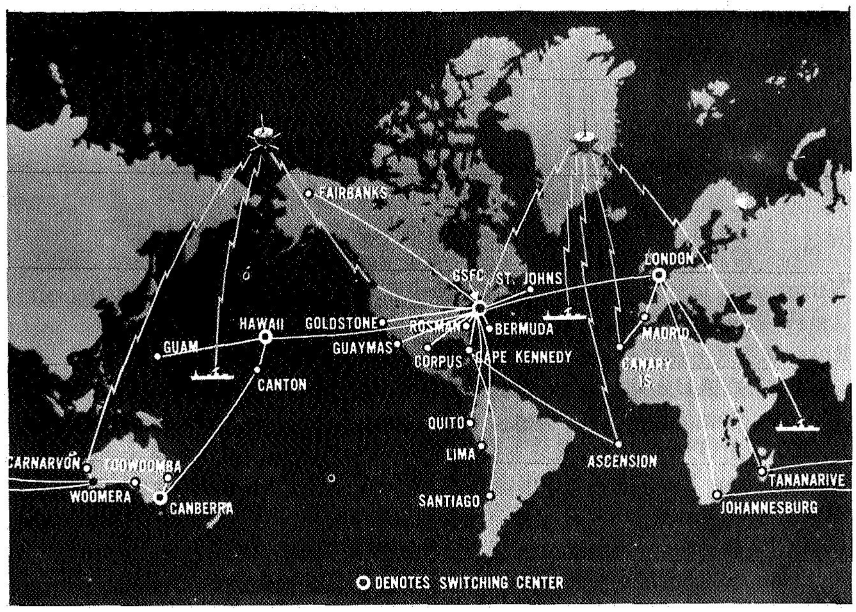

Figure 6–2. NASA communications network.

As an integral part of NASCOM, communications switching centers have been established at major locations such as Goddard, London, Madrid, and Canberra (Australia) to maximize circuit-sharing.

Although network operational activity was heavy, substantial progress was made in augmenting the NASCOM to meet the requirements of the Apollo program. The centralized command control exercised by the flight director of the complex Apollo lunar missions from the Mission Control Center in Houston will require a much larger volume of real-time data to be transmitted through the NASCOM network as well as more reliable communications links between the tracking stations and the Mission Control Center.

The increased transmission requirement was being met by expanding the high-speed data switching centers and by adding special data transmission and data handling equipment at NASCOM terminals. For the reliability requirement, it will be necessary to make use of communications satellites. NASA completed negotiations with the Communications Satellite Corporation to provide service via communications satellites to the 3 land stations (Canary Island, Ascension, and Carnarvon) and the 3 instrumentation ships of the MSFN.

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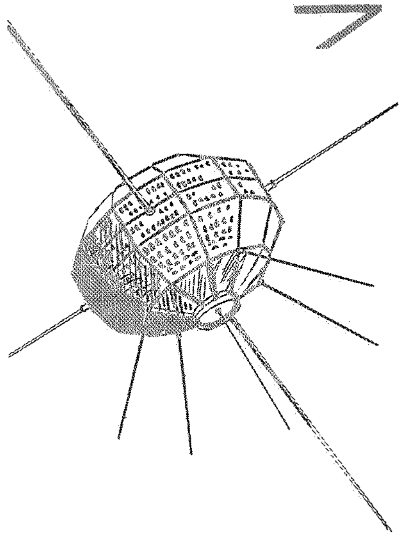


INTERNATIONAL AFFAIRS

International cooperative space and atmospheric projects and international support activities continued and new ones were developed. The NASA Administrator personally emphasized the Agency's continuing interest in multilateral space activities in Europe during visits to England and Germany.

COOPERATIVE PROJECTS

During the last half of 1966, continued growth characterized NASA's cooperative projects in space research. Five new agreements were concluded with the space authorities of other countries. Also, a British experiment was accepted for flight on the Nimbus spacecraft, bringing to 18 the number of foreign experiments accepted for flight on NASA satellites. In the sounding rocket field, ten countries cooperated with NASA; launchings were conducted in Argentina, Brazil, India, Pakistan, and Spain; and new agreements were reached with Argentina, Brazil, and Japan.

On October 15, Spain joined the nations engaging in space research by conducting the first scientific sounding rocket experiment from Spanish soil. This experiment initiated a series of meteorological launchings with technical assistance and ground support equipment supplied by NASA under a cooperative arrangement with the Spanish Space Committee (CONIE).

Canada

On September 28, the Canadian-built Alouette I satellite completed its fourth year of successful operation in orbit. During this time, this satellite traveled 576 million miles, responded to 52,000 commands, and provided 7800 hours of telemetry resulting in 1.69 million ionograms. Alouette I has had the longest and most successful life of any satellite put into space. Also, Alouette II completed its first year of successful performance.

European Space Research Organization (ESRO)

In the first arrangement of its kind, NASA and ESRO concluded a Memorandum of Understanding on December 30, 1966, providing for the purchase of launchings from the United States for ESRO satellites. ESRO will reimburse NASA for costs associated with the launching—vehicle, range use, and initial tracking and data acquisition.

Under the Memorandum of Understanding, a separate contract will be signed for each satellite launching. Negotiations were underway on the contract for HEOS-A (Highly Eccentric Orbit Satellite) designed to be launched by a U.S. Thor Delta booster.

At the close of the period, the two NASA/ESRO cooperative satellite projects (ESRO I and II) were progressing according to plan. ESRO II is scheduled to be launched by a NASA Scout rocket from the Western Test Range in early 1967 to study solar radiation and cosmic rays in a high polar orbit. ESRO I, also a Scout-launched satellite, for study of high energy particles and their effect on the ionosphere, will be ready late in 1967.

France

On November 13, the French National Center for Space Studies (CNES) conducted a cooperative experiment with NASA involving daytime photography of a sodium vapor cloud from the Gemini XII spacecraft. The Gemini crew endeavored to make "hatch open" pictures of the cloud far below them which had been released by a French Centaure sounding rocket launched from the range at Hammaguir in Algeria. The experiment was not successful. However, effort is being made to perfect the technique and the experiment may be repeated on an early Apollo earth orbital mission. If successful, it is expected to improve the capability of studying daytime wind velocity vectors in the high atmosphere.

At the end of 1966, the second cooperative satellite project with France—the FR–2 (EOLE)—was progressing on schedule. This spacecraft will test the feasibility of a meteorological re-

porting system in which a satellite gathers data from approximately 500 constant-level balloons drifting in the atmosphere. The FR–2 satellite is scheduled for launch in 1969 on a Scout rocket from the NASA Wallops Station.

Germany

On November 10, a Nike-Apache rocket was successfully launched from Churchill Research Range, Canada, to test instrumentation for the German Research Satellite 625 A–1, scheduled for launching in 1968. Another instrumentation test is to be flown on a Javelin rocket from Natal, Brazil, in early 1967. Definition of the satellite payload itself is scheduled for mid-1967, with launching late in 1968.

Figure 7–1. German scientists preparing to photograph barium clouds.

On July 14, the BMwF (BundesMinisterium fuer wissenschaftliche Forschung) continued its cooperative sounding rocket program with the launching of a German-built variable frequency impedance probe on a NASA Nike-Apache rocket from Wallops Station. The instrument measured electron density in the ionosphere.

Cooperative investigations into the characteristics of ionized chemical clouds in space continued on September 24–25 with the successful launching of two German-built barium release experiments from Wallops Station (Fig. 7–1.) The payloads, prepared by the Max Planck Institute of Extraterrestrial Physics, were boosted into space by a Javelin and a Nike-Apache rocket. Barium and copper oxide mixtures were released into space at altitudes up to 570 miles. The huge clouds, changing in color from green to pink to blue, could be seen from most areas in the northeast United States as they oriented along the earth's magnetic field lines.

On November 20, the National Center for Atmospheric Research conducted the first of a series of cooperative high-altitude balloon experiments with the Fraunhofer Institute of Freiburg, Germany. Instruments prepared by the Institute to obtain high-resolution photography and spectra of the fine structure elements of the solar atmosphere were test flown from NCAR's Balloon Flight Station at Palestine, Texas, on a mylar scrim balloon furnished by NASA under a cooperative agreement.

India

The cooperative sounding rocket series between NASA and INCOSPAR continued with the July 7 launching, from the Thumba Equatorial Rocket Launching Station, of a Nike-Apache carrying an Indian-built payload. The purpose of the launching was to investigate the equatorial electrojet by means of magnetometer instrumentation.

Italy

Preparations entered the final phase for the launching during 1967 of the second San Marco air density satellite. This cooperative project between NASA and the Italian Space Commission involves the launching on a Scout vehicle of an air density measurement satellite into a low-altitude near-equatorial orbit from an Italian towable platform in the Indian Ocean off the coast of East Africa. It will be the first orbiting of a spacecraft from such a portable launch site.

Japan

On December 26, NASA, the Japanese Science and Technology Agency, and the Japanese Meteorology Agency concluded a cooperative agreement providing for the joint testing in 1967 of a series of Japanese-made MT–135 meteorological sounding rocket systems and comparable U.S. systems (Arcas and Boosted-Dart) from NASA's Wallops Station. Flight and operating characteristics will be verified and data on stratospheric winds and temperature will be obtained.

Arrangements made jointly with NASA and the Canadian Defense Research Telecommunications Establishment enabled the Japanese Radio Research Laboratories (RRL) to begin receiving telemetry data from the Alouette I and II satellites at its Kashima facility on August 15.

Norway

Discussions with the Norwegian Committee on Space Research in December set the basis for conducting joint experiments on seven sounding rockets in 1967. The purpose of these experiments will be to study Polar Cap Absorption (PCA) events, investigate auroral phenomena, and obtain information on the D-region of the ionosphere.

On August 15, Norwegian ionospheric physicists began to receive signals from the Alouette II satellite at their Tromso station.

South America

Solar Eclipse of November 1966:—Under agreements concluded by NASA with the Argentine Space Commission (CNIE) and the Brazilian Space Commission (CNAE), some 29 cooperative sounding rocket launchings were conducted in conjunction with the total solar eclipse that occurred in the southern hemisphere on November 12. Objectives of these scientific investigations were to observe wind, temperature, and ozone changes in the upper atmosphere and to determine fundamental particle densities, temperatures, and fluxes as well as solar X-ray sources and intensities. On eclipse day, Argentina launched 12 payloads on boosted Arcas sounding rockets to altitudes of about 60 km from Tartagal, Argentina. Brazil launched 17 Nike vehicles of different configurations (Nike/Apache, Tomahawk, Hydac, and Javelin) to altitudes up to 700 km from a newly established site at Cassino, Brazil.

Inter-American Experimental Meteorological Rocket Network (EXAMETNET):—Both Argentina and Brazil continued active participation in EXAMETNET with small meteorological rocket

launchings coordinated with NASA launchings at Wallops Station. Argentina used 13 and Brazil 17 boosted-Dart and Arcas rockets during the reporting period. This work is planned to continue at a rate of about 30 launchings per country per year.

Other Projects:—The Brazilian Space Commission launched seven acoustic grenade payloads on Nike-Cajun rockets from the Natal range during this period to measure wind, temperature, pressure, and density in the 40–100 km region of the atmosphere. These launchings were coordinated with similar ones from Wallops Station, Churchill Research Range, Canada, and Point Barrow, Alaska. During 1966, Brazil made nine such launchings in a twelve-rocket series expected to be completed in early 1967.

An active year of cooperative projects at the Natal equatorial range was concluded on December 12 with the launching of a NASA Aerobee 150 sounding rocket. The rocket was launched to an altitude of 205 km to investigate new X-ray sources in the southern hemisphere. The payload was prepared by the Catholic University of America, Washington, D.C.

South Asia

International Indian Ocean Expedition (IIOE):—The Pakistan Space Commission (SUPARCO) and the Indian National Committee for Space Research (INCOSPAR) each launched 4 boosted-Dart meteorological sounding rockets with chaff payloads. This brought to 59 the number of launchings in the two countries since the series began in 1964. All of these launchings have supplemented the work of the International Indian Ocean Expedition (IIOE), a program designed to gain a better understanding of the Indian Ocean basin through comparison of geophysical, oceanographic, and atmospheric data.

Spain

Beginning October 15 with the launching of a British-Built SKUA rocket and the subsequent launching of U.S.-built boosted-Dart meteorological sounding rockets, Spain commenced operation of its scientific rocket research range at Campo de Arenosillo near Huelva on the Atlantic coast in southwestern Spain. By the end of the year, 7 launchings of U.S. weather rockets had been conducted under a cooperative agreement between NASA and the Spanish Space Committee (CONIE). NASA trained the Spanish launch crew and is lending the radar and other ground support equipment. The Spanish are providing the rockets, launch site, and range operations.

United Kingdom

Toward year's end, the UK–3 satellite project moved into its final phase, with systems compatibility and vehicle fit checks underway. This, the third U.S./U.K. cooperative space research project, was on schedule and slated for launching early in 1967.

An additional British experiment was selected for flight on a NASA satellite, bringing to eleven the number of U.K. packages accepted to date. The Reading University "Selective Chopper Radiometric Temperature Probe" is to fly on Nimbus D in 1970.

U.S.S.R.

Experimental two-way transmission of satellite weather data over a special shared-cost facsimile link between Suitland, Maryland, and Moscow began in September, when Soviet satellite data, including both cloud-cover photographs and nephanalyses, became available. Reciprocal exchange of conventional meteorological data between the U.S. and the U.S.S.R. continued over the same link.

European Discussions

The NASA Administrator visited London and Bonn briefly in September to observe space activity in England and Germany. In Great Britain, he met with British officials to discuss U.S. experience in government-industry-university relationships and the benefits derived from space technology. In Bonn, the Administrator met with the Minister of Scientific Research and other German leaders to discuss means of increasing U.S./German space cooperation. Agreement was reached to proceed with negotiations on the details of a second German cooperative satellite project—an aeronomy research spacecraft. The first steps were also taken to consider a German proposal for a joint solar probe experiment in the early 1970's.

During these visits, the Administrator again emphasized the continuing interest of NASA in the future of multilateral space activities in Europe and the readiness of the United States, as manifested in the President's offer of December, 1965, to enter into multilateral arrangements with European nations for advanced space cooperation.

Exchange of Scientific and Technical Information

Under informal arrangements, NASA maintained a program of document exchange with 277 institutions located in 42 countries.

Cooperation Through United Nations

NASA's General Counsel served on the United States delegation to the meeting of the Legal Subcommittee of the United Nations Committee on the Paceful Uses of Outer Space. This subcommittee succeeded in drafting a treaty on principles governing the activities of states in the exploration and use of outer space including the moon and other celestial bodies which the UN General Assembly commended for signature and ratification on December 19, 1966.

The Assistant Administrator for International Affairs served as United States Representative at the September meeting of the Working Group of the Whole established by the United Nations Committee on the Peaceful Uses of Outer Space. The purpose of this Working Group is to examine the desirability, organization, and objectives of a United Nations space conference. This Assistant Administrator also served as alternate United States Representative at the September meeting of the committee proper.

OPERATIONS SUPPORT

During the second half of 1966, negotiations of intergovernmental agreements were continued with the United Kingdom to establish new or continue existing NASA tracking facilities. The NASA station in Nigeria was discontinued. An agreement was signed, permitting ESRO to establish a telementry-command station in Alaska. Approvals were obtained from several countries for stationing temporary facilities for support of the National Geodetic Satellite Program.

Nigeria

Following conclusion of Project Gemini in November, NASA discontinued the Kano, Nigeria, tracking station. This station will not be required for support of Project Apollo.

United Kingdom

The intergovernmental agreement for the NASA tracking and communications station at Winkfield, England, was extended until March 31, 1967, by an exchange of notes dated December 28, 1966 and January 1, 1967. In addition, NASA continued to negotiate agreements for establishing and operating tracking stations on Antigua and Grand Bahamas in support of Project Apollo.

National Geodetic Satellite Program

Arrangements were made with Denmark, Norway, Italy, Portugal, Iran, and Japan for temporarily locating geodetic satellite observation cameras within their territories in connection with the National Geodetic Satellite Program (NGSP).

ESRO

An international agreement was concluded between the United States and the European Space Research Organization (ESRO) on November 28, 1966, providing for the establishment of an ESRO telemetry-command station near Fairbanks, Alaska. The purpose of this station is to receive data from scientific satellites. This is the first foreign space station on United States territory. NASA is designated as Cooperating Agency for matters relating to implementation of this agreement.

PERSONNEL EXCHANGES, EDUCATION AND TRAINING

During the second half of 1966, over 2,700 foreign nationals from 92 countries and separate jurisdictions visited NASA facilities for scientific and technical discussions or general orientation. (Fig. 7–2.)

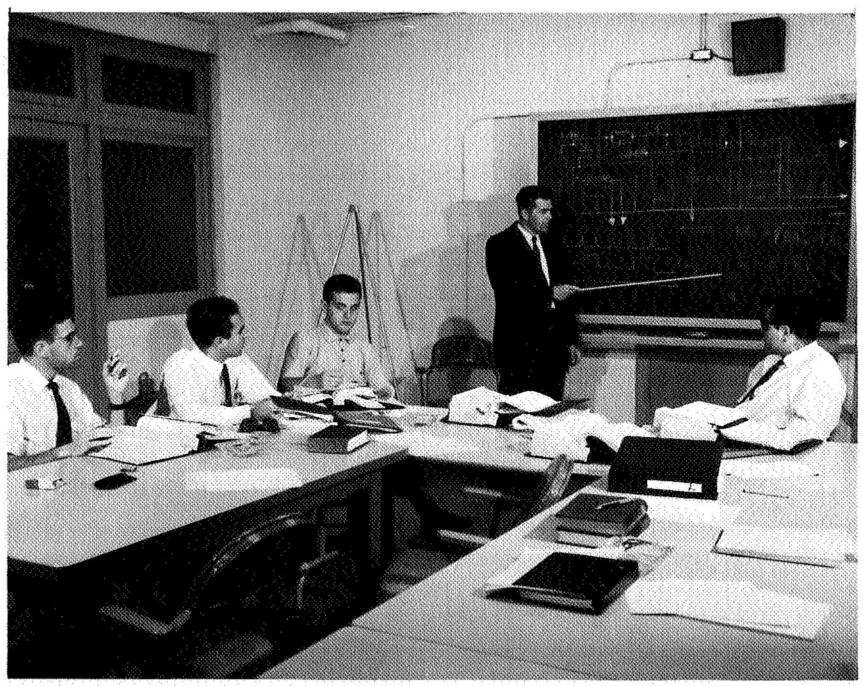
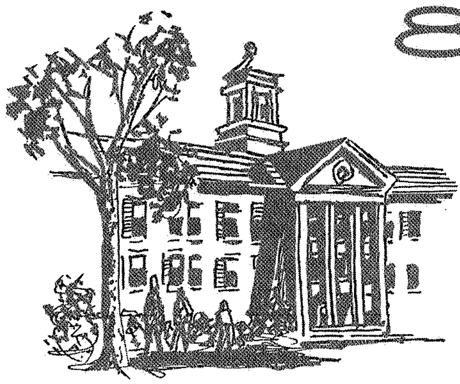


Figure 7–2. Spanish trainees in radar class at Wallops Station.

Under the NASA International University Fellowship Program, 45 students either entered the program or continued their studies, and thirteen countries and 18 universities participated. They were supported by their national space research sponsors or by the European Space Research Organization. This program is administered for NASA by the National Academy of Sciences.

One hundred and one postdoctoral and senior postdoctoral associates from 26 countries carried on research at NASA centers, including the Jet Propulsion Laboratory. This program is also administered by the National Academy of Sciences and is open to U.S. nationals.

Twenty-six scientists, engineers, and technicians representing Argentina, Brazil, France, India, Italy, Spain, and ESRO, here at their own expense, received training in space technology at Goddard Space Flight Center and Wallops Station in connection with cooperative projects.



8 GRANTS AND RESEARCH CONTRACTS ACTIVITIES

In addition to its in-house activities, NASA conducts an extensive grants and research contracts program to provide research, training, and research facilities at colleges and universities. The major portion of the program comprises project research directly supporting the Agency's mission objectives. Complementing project research is the Sustaining University Program, which broadly enhances the contribution of educational institutions to the national aeronautics and space effort.

SUSTAINING UNIVERSITY PROGRAM

Training

Training activities, which include predoctoral traineeships and special programs at levels ranging from faculty to undergraduate, are intended to help develop the necessary supply of well trained scientists and engineers to support the national space program.

The predoctoral program is the largest of the Sustaining University Program training activities. In September 1966, 1,335 new students began studies, making a total of 3,681 NASA trainees studying full-time toward the doctorate at 152 universities in 50 states and the District of Columbia. The students were distributed among disciplines as follows (cf. p. 162, *14th Semiannual Report*):

Discipline	*FY 1966 Percent*
Physical Sciences	50.0
Engineering	35.2
Life Sciences	11.1
Behavioral Sciences	3.5
Other	.2
Total	100.0
Total Number of Students	1,335

Institutions awarded NASA predoctoral training grants are shown in Appendix R. Since the program began, 435 NASA trainees have received their Ph.D. degrees—237 in the physical sciences, 139 in engineering, 36 in life sciences, 18 in behavioral sciences, and 5 in other areas. They made these initial career choices: University research and/or teaching-199; Postdoctoral fellowships or Fulbright awards-65; employment in government laboratories-29; employment in industry-126; military service-16.

NASA continued sponsorship of the summer faculty fellowship program (*15th Semiannual Report*, p. 132) which seeks to stimulate the exchange of ideas between participants and NASA and to enrich and refresh research and teaching at their institutions. Twelve universities and seven field centers cooperated in offering research and study opportunities to about 160 faculty members.

NASA also sponsored a ten-week summer faculty fellowship program in engineering design which was conducted at Stanford University with the cooperation of the Ames Research Center. The program's principal objective was to allow the fellows to increase their competence and to develop concepts which will enable them to organize multidisciplinary engineering systems design courses at their home institutions. During the summer of 1966, 15 faculty members worked on a preliminary design study of an advanced solar probe. In addition, the Agency sponsored summer institutes at Columbia University, the University of Miami, and the University of Southern California where about 160 senior undergraduates received six weeks of specialized training in space science and technology. Support of advanced training in aerospace medicine was continued at Harvard University and Ohio State University where a few selected physicians receive advanced training in the environmental problems of man in space.

Under the NASA, National-Research-Council-administered resident research associate program (*15th Semiannual Report*, p. 132) 122 scientists worked as Research Associates at the following centers:

Goddard Space Flight Center		60
Institute for Space Studies, New York	18	
Greenbelt, Maryland	42	
Ames Research Center		33
Langley Research Center		9
Marshall Space Flight Center		7
Jet Propulsion Laboratory		7
Manned Spacecraft Center		4
Electronics Research Center		2
Total		122

Research

The sustaining university program sponsored multidisciplinary space-related research in 48 educational institutions and supported special projects at 5 universities (City University of New York, Columbia University, State University of New York, Yale University, Yeshiva University) directly related to the astronomy and physics efforts of the Goddard Space Flight Institute for Space Studies. The institutions holding research grants are:

Adelphi University
University of Alabama
University of Arizona
Brown University
University of California (Berkeley)
University of California (Los Angeles)
California Institute of Technology
University of Cincinnati
Colorado State University
University of Denver
Drexel Institute of Technology
Duke University
University of Florida
George Washington University
Georgia Institute of Technology
Graduate Research Center of the Southwest
University of Houston
University of Kansas
Kansas State University
Louisiana State University
University of Louisville
University of Maine
University of Maryland
Massachusetts Institute of Technology
University of Miami
University of Minnesota
University of Missouri (Columbia)
Montana State University
New Mexico State University
New York University
University of Oklahoma
Oklahoma State University
University of Pennsylvania
Pennsylvania State University
University of Pittsburg
Purdue University
Rice University
University of Southern California
Southern Methodist University
University of Tennessee
Texas A.&M. University
University of Vermont
University of Virginia
Virginia Polytechnic Institute
Washington University (St. Louis)
West Virginia University
College of William and Mary
University of Wisconsin

Programs at George Washington University, Louisiana State University, and the University of Southern California were initiated, and the program was extended into one additional state, Louisiana. The grant to George Washington University will en-

able the university to develop the ability to contribute inputs to NASA related studies of national policy involving science. technology, and public administration. The research grant to the University of Southern California emphasizes improved communications and interaction between the surrounding industry and the University.

The work at Louisiana State University stresses activities in the School of Engineering and will help to develop relationships between the University, NASA Centers, and surrounding industry. The space-related research at the University contributes to the economic development of the state, the region, and the nation.

Research Facilities

Six facilities (Texas A&M, Maryland, Rice, New York University, Georgia Tech, and Arizona) were completed, bringing the total to 23 for the program. The completed laboratories (Table 8–1) are expected to accommodate about 2300 scientists, engineers, and others working on space-related problems.

The Space Science Laboratory of the University of California, Berkeley, already completed and occupied, was dedicated; and the Universities of Denver and Florida initiated construction with ground-breaking ceremonies. Construction also began on the Space Science Building at the University of Minnesota. New facilities grants were awarded to the University of Washington and the University of Wisconsin, and the latter started construction. The status of the 12 active grants, including those awarded during this period is summarized in Table 8–2.

MANAGEMENT OF GRANTS AND RESEARCH CONTRACTS

Procedures for processing and administering proposals, grants, and research contracts were further improved and streamlined. A mechanized monthly status report, listing all proposals forwarded to program offices for evaluation, the length of time the program office has had each proposal for evaluation, and indicating those funded or withdrawn during the month was developed and is sent monthly to each program office or center.

Letter of Credit procedures were implemented at Princeton University to finance advance funded contracts. Procurement regulations providing standard clauses for financial management reporting on research contracts with universities and nonprofit institutions were developed and approved; guidelines for auditing training grants were developed; and audits were requested at four institutions which have received NASA training grants. The first cost-sharing report for 546 grants to 149 institutions was submitted to the Bureau of the Budget. Procedures were

Table 8–1. Completed Research Facilities—December 31, 1966

Fiscal Year Grant Awarded	*Institution*		*Area (1000 SF)*	*Cost ($1000)*
1962	RPI	Materials Research	60	$1,500
Do.	Stanford	Exobiology	15	535
Do.	Chicago	Space Sciences & Astronautics	45	1,749
Do.	Iowa	Physics & Astronomy	24	536
Do.	California (Berkeley)	Space Sciences	44	1,990
Do.	Harvard	Biomedicine	5	151
1963	Minnesota	Physics	17	$ 542
Do.	Colorado	Atmospheric & Space Physics	32	792
Do.	California (Los Angeles)	Space Sciences	69	2,000
Do.	Michigan	Space Sciences & Engineering	56	1,436
Do.	Pittsburgh	Space Sciences	47	1,497
Do.	Princeton	Propulsion Sciences	26	625
Do.	Lowell	Planetary Sciences	9	237
1964	Texas A&M	Space Sciences	34	$1,000
Do.	Maryland	Space Sciences	77	1,500
Do.	Southern California	Human Centrifuge	4	160
Do.	Rice	Space Sciences	68	1,600
Do.	Purdue	Propulsion Sciences	4	840
Do.	Washington (St. Louis)	Space Sciences	25	600
Do.	New York	Aeronautics	13	582
Do.	Georgia Tech	Space Sciences & Technology	51	1,000
Do.	Arizona	Space Sciences	51	1,200
Do.	P.I.B.	Aerospace Sciences	16	632
TOTALS			792	$22,704

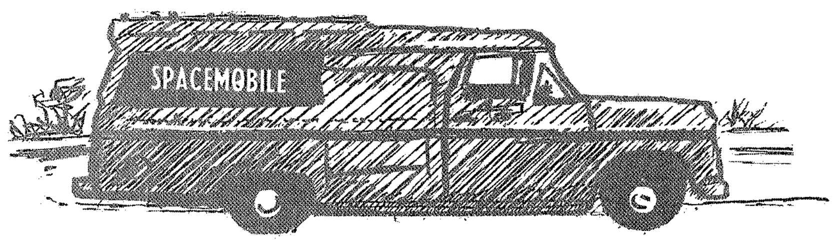
Table 8-2. Research Facilities in Progress—December 31, 1966

Fiscal Year Grant Awarded	*Institution*	*Topic*	*Area (1000 SF)*	*Percent Complete*	*Cost ($1000)*
1963	M.I.T.	Space Sciences	75	45	$3,000
Do.	Wisconsin	Theoretical Chemistry	12	90	365
1964	Illinois	Space Sciences	51	80	1,125
Do.	Cornell	do	38	99	1,350
1965	Case Inst. of Technology	Space Engineering	69	Design	2,226
Do.	Rochester	Space Sciences	35	Bid	1,000
Do.	Florida	do	53	15	1,190
Do.	Minnesota	do	70	10	2,500
Do.	Denver	do	41	30	900
Do.	Stanford	Space Engineering	65	Bid	2,080
1966	Wisconsin	Space Science & Engineering	58	1	1,700
Do.	Washington	Aerospace Research	40	Design	1,500
TOTALS			607		$18,936

being developed to implement requirements of Phase II of the Committee on Academic Science and Engineering reporting requirements.

Between July 1 and December 31, 1966, the Office of Grants and Research Contracts received 1,602 unsolicited proposals; it processed 597 procurement requests totaling $61.2 million and 287 grants and contracts totaling $31.6 million.

9 INFORMATIONAL AND EDUCATIONAL PROGRAMS



NASA continued to expand its specialized informational-educational activities and services and improve its methods of disseminating scientific and technical information. Throughout the U.S. the Agency helped elementary and secondary schools meet their instructional needs in space science and technology by conducting summer courses and arranging workshops for teachers. NASA's spacemobile lecturers reached millions of students and their instructors in this country alone, and its educational exhibits were seen by millions of more Americans. An advanced computer was being programmed to provide scientists and engineers with aerospace literature from the Agency's information system more quickly and at lower unit cost. And, through its Technology Utilization Program, NASA announced and then disseminated facts on commercially-useful innovations resulting from aerospace research and development to encourage industrial use for the benefit of the public.

EDUCATIONAL PROGRAMS AND SERVICES

NASA helped elementary and secondary schools meet their instructional needs in space science and technology by assisting colleges, universities, and local school districts in 47 states in conducting 178 summer courses and workshops enrolling over 10,000 teachers. This assistance included supplying NASA publications, audiovisuals, and exhibits, and providing spacemobile lecturers and other speakers, as well as help (other than funds) in planning, organizing, and conducting the courses and workshops. Through its speakers, consultants, and other educational specialists, the

Agency also participated in long-range national, regional, and state programs to assist school administrators in developing courses incorporating materials from the space sciences. Such programs were underway with Massachusetts, Minnesota, South Dakota, and Texas, and with the Southern States Work Conference (an organization of educational leaders from 13 States in the South).

In cooperation with regional associations of planetarium directors, curriculum-enrichment materials in the space sciences were being planned for the increasing number of school and community planetaria. In addition, curriculum resources for secondary school teachers in the space-related aspects of chemistry were being developed at Ball State University (Muncie, Indiana), biological science at the University of California (Berkeley), physical science at Columbia University, mathematics at Duke University, earth-space science by the National Science Teachers Association, physics at Texas A. & M. University, and industrial arts at Western Michigan University (Kalamazoo). Publications in biology, physics, earth-space science, and industrial arts should be ready for school use in the fall of 1966. A space science lexicon for elementary school teachers was being prepared at Oregon State University (Corvallis).

Spacemobiles

NASA's 26 spacemobile units provided lectures and demonstrations in school auditoriums, classrooms, and laboratories for 1,153,039; and local radio and TV programs reached an estimated 3,390,000. In addition to scheduled school programs, spacemobile units undertook two special programs—one calling for increased attention to schools in culturally-deprived areas and another for one- and two-day visits to Job Corps camps. Also spacemobile lecture-demonstrations were offered in Argentina, Australia, Germany, Guinea, India, and the Netherlands. The spacemobiles were manned by native speakers trained by NASA. (The nations served financed this service.)

Youth Programs

To encourage elementary and secondary school classes to visit the John F. Kennedy Space Center, the Center's education office, in October, reduced its admission fees for school children and scheduled briefings for young people. In October, November, and December, 59 school groups and 5,416 students from Florida, neighboring states, and from Puerto Rico took advantage of this special program to visit the Center. Reflecting an increasing interest in space on the part of young people, NASA headquarters

answered over 600 letters from high school students inquiring about careers in space science and engineering.

The Agency also arranged with the National Science Teachers Association to conduct a series of nine Youth Science Congresses in the spring of 1967 at NASA research and flight centers. Held every other year, the Congresses bring together 150 to 175 promising secondary school juniors and seniors who discuss their research in the space sciences with one another and with scientists from NASA, industry, and the universities.

Educational Publications and Films

NASA released 11 new educational publications, issued updated editions of several others, and produced 17 new motion pictures. They are described in appendix L.

Over 34,740 requests from teachers, students, professionals, and the general public for publications and 2,102 for motion pictures were received at the Agency's headquarters. Motion picture film catalogued and stored in NASA's depository reached 8,741,240 feet, and 90,293 feet of film were made available to producers of educational and documentary movies and telecasts.

Educational Television and Radio

Recognizing the new dimension that color telecasts offer more and more viewers and noting the still-increasing number listening to radio, NASA increased its efforts to provide this growing audience with educational programs on space science and technology.

The Agency was preparing to release a new group of 30-minute television "specials" on topics ranging from advanced theories of the universe to a study of international cooperation in space at the Guaymas (Mexico) Tracking Station. Most of this series will be in color.

Work also began on another new series of half-hour television "specials" to follow the highly successful *Science Reporter*. The *Science Reporter*, after concluding its run on educational TV throughout the country, was distributed to commercial stations. This series was programmed in 44 States, Puerto Rico, the Virgin Islands, and Samoa by 41 of the top 50 TV outlets, including all of the top ten. Programs covered a wide variety of subjects in space science and technology.

In addition, NASA continued producing and distributing its monthly five-minute television program *Aeronautics and Space Report*. The telecasts reviewed the wide spectrum of the Agency's

activities—manned space flight (Projects Mercury, Gemini, and Apollo), the X–15 aircraft program, scientific satellites, and bioastronautics.

Also, NASA furnished individual TV stations, networks, and producers in the United States, Canada, and Great Britain with guidance, information, motion pictures for television, and other visual materials.

In radio, the Agency continued to produce and distribute its weekly five-minute program *Space Story* covering such varied topics as sounding rockets, lunar probes, and scientific spacecraft. The 15-minute monthly programs *NASA Special Report* were also continued, with emphasis on the Apollo lunar mission and in-depth studies of its problems. Other continuing services included: *Audio News Features,* a series of interviews released periodically, and *NASA Space Notes,* a quarterly series of short informational programs. The series of 13 half-hour radio programs, *Their Other World,* concluded its original run after being carried on over 800 stations in the country.

EXHIBITS

NASA answered about 317 requests for educational exhibits which were seen by approximately 14,100,000 persons. The Agency accepted an invitation from Jackson, Michigan to develop a space exposition sponsored by the entire community in and around that city. (Fig. 9–1.) Over 125,000 students from schools as far away as Ohio visited this exposition. NASA also accepted a similar invitation from Greensboro, North Carolina. Initiated by the Junior Chamber of Commerce, this event was later endorsed by the entire community and programmed for display December 2 through 11. About 50,000 persons, including hundreds of students from schools in and around Greensboro, viewed the exhibit.

Plans were completed for NASA's participation in the Expo '67 World's Fair (April 28—October 27, 1967) in Montreal and the Paris International Air Salon (May 26—June 4, 1967).

Continuing to support the overseas program of the U.S. Information Agency, NASA loaned USIA the Gemini X spacecraft (flown by Astronauts Young and Collins in July) for a tour of Tokyo, Kita-Kyushu, and Osaka in Japan. The tour—sponsored by the Japanese newspaper *Asahi*—gave 108,000 Japanese an opportunity to see a real spacecraft. Later, the spacecraft was shipped to Australia for a six-month tour sponsored by the Australian Government's Department of Supply.

Figure 9–1. Midwest Space Fair, Jackson, Mich., Sept. 24 — Oct. 2, 1966.

HISTORICAL PROGRAM

The first in NASA's Administration and Management History Series, Dr. Robert Rosholt's *An Administrative History of NASA, 1958–1963,* was issued by the Agency in July. A second printing of the history (SP–4101, $4, Superintendent of Documents, U.S. Government Printing Office) began in September. The first of NASA's program histories, *This New Ocean: A History of Project Mercury* by Loyd S. Swenson and Charles C. Alexander, University of Houston, and James M. Grimwood, Manned Spacecraft Center, was also published. This history (SP–4201) is sold by the Superintendent of Documents for $5.50, cloth. In addition, the latest in the Agency's series of annual chronologies—*Astronautics and Aeronautics, 1965* (SP–4006)—was issued in November. A list of the *Publications of Hugh L. Dryden* (HHN–59 Rev.) was made available in July, and listings of Dr. Dryden's many unpublished writings were being prepared.

SCIENTIFIC AND TECHNICAL INFORMATION

NASA's computerized scientific and technical information system is made up of more than 500,000 items of aerospace literature

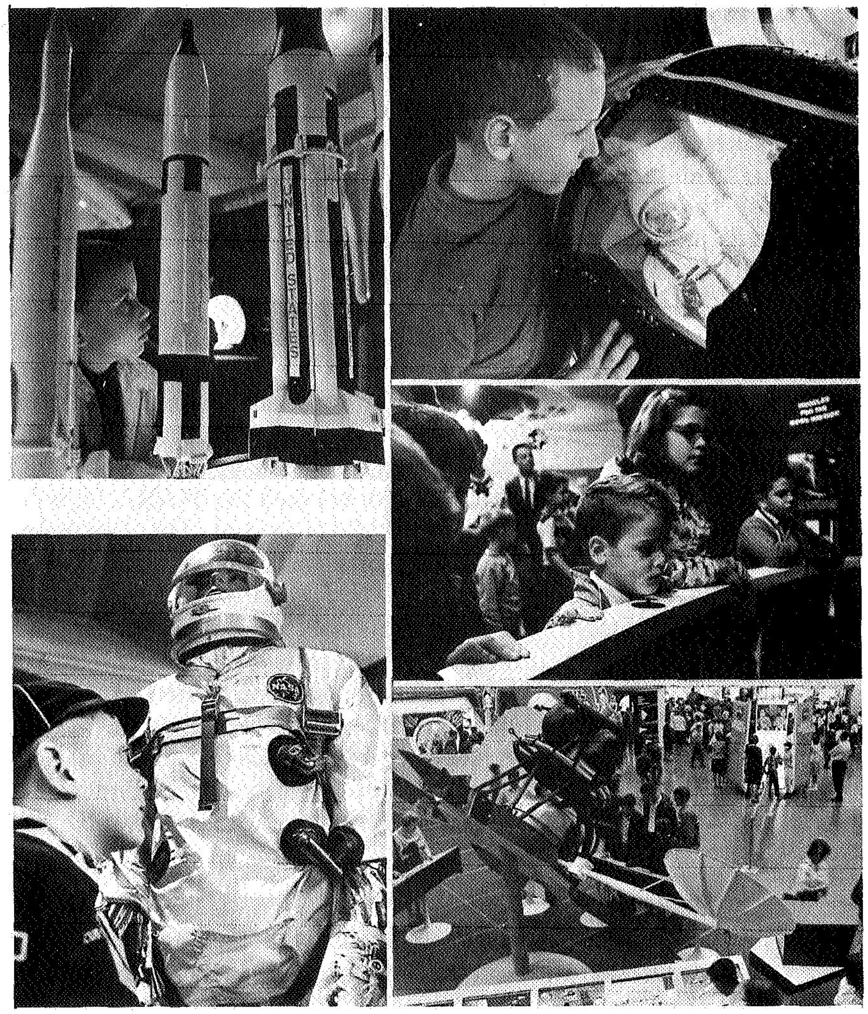


Figure 9–2. The Space Age generation inspects NASA exhibits.

and is growing at the rate of 100,000 items annually. For more efficient processing of this burgeoning supply of information, the Agency was testing modified procedures and developing cooperative arrangements with other agencies.

Processing Information

Computers help produce from this very large collection such information products and services as announcements, indexes, literature searches, and distribution lists. An advanced computer was being programmed to provide a wider variety of services at

a faster rate and more efficiently, but at lower unit costs. This reprogramming evolves from current procedures in order not to make available materials obsolete nor break processing continuity.

Tests of procedures for announcing current information of specific interest to individual scientists and engineers were being expanded to determine the extent of their common interests. As groups of these common interests are identified, one computer output will be able to serve more individuals, offering selective dissemination of information with less expenditure of computer time.

Typically, documentary information is stored and retrieved by using terms to describe the contents of each item, and indexing terms used by an information system serve as a convenient thesaurus to query the system. A single thesaurus for aerospace science and technology, compatible with those of other government information services, was being developed for NASA. It will not only standardize usage within NASA's system but also help produce comparable and relevant results when cross-questioning other systems.

NASA's information system is designed to support aerospace programs by providing information regardless of source. Since other agencies also prepare documents distributed through NASA's scientific and technical information system, the Agency arranged for certified NASA users to request Department of Defense documents directly from the Defense Documentation Center rather than through the NASA system, thus streamlining processing of such requests.

Technical Publications

A selected list of the Agency's scientific and technical publications released during the last six months of 1966 is given in appendix M.

TECHNOLOGY UTILIZATION

To increase the return on the public investment in aerospace research and development, NASA continued to identify, evaluate, disseminate, and publish its results so as to encourage its use primarily by the non-aerospace community. Inventions, innovations, improvements, and discoveries made by NASA and its contractors—documented and reported for public use during the last half of 1966—more than doubled those for the last six months of 1965.

Publications

The *Tech Brief* (a one-page description of an innovation) remained the principal means of announcing commercially useful

innovations. In 1966, 714 *Tech Briefs* were issued compared to 378 in 1965. In addition, 12 state-of-the-art *Technology Surveys* were published, while 21 were under preparation. Among them were: "Solid Lubricants"; "Cardiovascular Monitoring"; "Adhesives, Sealants, and Gaskets"; and "Vacuum Switchgear."

The first 25 AEC–NASA *Tech Briefs* were issued and 70 others were being prepared. In May, NASA and the Atomic Energy Commission agreed upon a joint experimental program under which the AEC would identify novel and commercially useful new technology generated in its programs, and NASA would evaluate, publish, and disseminate that new technology through its Technology Utilization Program. The AEC–NASA *Tech Briefs* were the first results of this interagency cooperation.

Also, two handbooks were published for NASA contractors defining the requirements of the new technology clause incorporated into all of the Agency's research and development contracts. The clause requires the contractor to report to NASA technology first conceived or first put into practice during the course of work under the contract.

Interagency Cooperation

Routine coordination continued between NASA and the Commerce Department's Office of State Technical Services which conducts programs to complement the NASA Technology Utilization Program. Efforts to apply advanced aerospace technology in solving the problems of physical rehabilitation also continued under an agreement between NASA and the Vocational Rehabilitation Administration. In addition, NASA undertook a joint program with the Justice Department (the Office of Law Enforcement Assistance) to alert researchers in crime prevention and law enforcement to the possible applications of aerospace technology in solving their problems.

University Contracts

Since NASA must develop costly computer programs due to the highly complex nature of the Nation's space activities, and because many of these can be applied elsewhere, the Agency has undertaken to identify, evaluate, and make such programs available through tapes, card decks, and program listings. Under contract to NASA, the University of Georgia disseminates this material to industry and to other potential users. The University's program is designed to become self-supporting soon on the basis of the fees that it charges to reproduce and distribute these computer-supplied items to requestors.

Under the terms of a NASA contract with Oklahoma State

University, a pilot project was begun to test the feasibility of rapidly introducing the results of the Agency's research and development into the classroom, particularly to graduate engineering students, through short courses and seminars. The University analyzes NASA scientific and technical reports in four fields and converts new information in them into monographs to enrich the curricula. In addition, NASA used documentary motion pictures made at its field installations and converted into "visual briefs" to show new scientific phenomena, illustrate new methods for gathering data, or to portray research results difficult to demonstrate in the classroom. These educational materials are being evaluated by professors—many of them authors of textbooks—in over a dozen cooperating universities.

Regional Dissemination Centers

During the last six months of this year, the experimental Regional Dissemination Centers made considerable progress toward serving a larger industrial audience. Fee-paying member companies increased from 131 in 1965 to 243; membership of small companies reached 37 percent of the total. The Aerospace Research Applications Center at Indiana University—the first computer-based Regional Dissemination Center established by NASA—will be self-supporting by the end of 1967. And a Regional Dissemination Center was started at the University of Southern California.

Biomedical Applications

Another experimental program—begun by the Agency in 1966 (*15th Semiannual Report,* p. 167)—would apply aerospace science and technology to biomedicine. In this program three small biomedical application teams, formed at three independent research institutes, have established interrelationships with groups at universities, clinics, and research hospitals carrying on research and development in biology and medicine. The teams help researchers identify and define problems impeding their research; the problems are reduced to non-disciplinary functional terms in *Problem Abstracts;* and the abstracts (largely coordinated by George Washington University under NASA contract) are the basis for a computerized search of the Agency's engineering and the physical sciences information that might be applicable to solving problems in the life sciences. *Problem Abstracts* are also sent to NASA field installation Technology Utilization Officers who contact installation scientists and engineers for their help.

The biomedical application teams have pinpointed over 70 im-

portant medical problems which may be solved by applying innovations from aerospace research and development. For example—

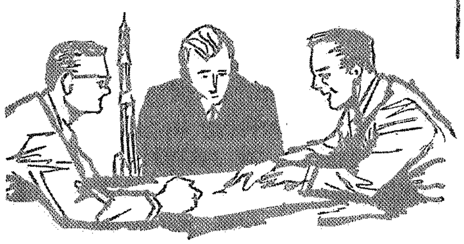
- A medical research group conducting studies to determine desirable levels of exercise for children with respiratory ailments, used a rubber mouthpiece to collect their exhausted breath while they performed various exercises. The mouthpiece was uncomfortable for the children. It often slipped causing the exhaled air to be lost and resulting in inaccurate measurements. This problem was solved by adapting a helmet used by Project Gemini astronauts for breathing.
- The principles upon which a micrometeorite detector (developed at Ames Research Center) was based enabled a biomedical research group at St. Louis University to detect subtle muscle tremors. The device may offer an improved means of diagnosing neurological disorders, such as Parkinson's disease, affecting muscle control.
- The Jet Propulsion Laboratory developed digital computer techniques for NASA to improve the quality of photographs of the moon and Mars transmitted by spacecraft. Experiments underway could apply these methods to provide clearer medical X-rays.

Other Non-Aerospace Applications

Additional examples of the application of innovations originating in NASA's Technology Utilization program include:

- An inorganic, silicate-based paint, developed at Goddard Space Flight Center, that has extreme resistance to abrasion, heat, and chemicals. It will soon be marketed for various commercial uses.
- A "sight switch" that allowed astronauts to actuate spacecraft controls by simply moving their eyes from side to side. It was adapted to control a motorized wheel chair, raise and lower a motorized hospital bed, and permit a paralyzed patient to communicate through a message panel.
- A "portable planetarium" designed by a technician at the Jet Propulsion Laboratory making lunar and planetary spacecraft trajectory models for NASA. Sold internationally, the device allows a student to determine at a glance the relative position of planets for any day from 1900 through the year 2000.

10 PERSONNEL, MANAGEMENT, PROCUREMENT, AND SUPPORT FUNCTIONS



NASA continued its efforts to assure the effectiveness and efficiency of its personnel, management, procurement, and other non-technical support activities. The overall aim of these efforts was to make certain that the Agency's space, aeronautics, and research missions would be competently staffed, soundly managed, and economically administered.

PERSONNEL

NASA's personnel endeavors were concentrated primarily on further professional updating and skill development programs for its employees. Previously established courses of instruction were continued, graduate and co-op training activities received increased attention, and additional seminars and lecture courses were provided. The Agency was able to focus its attention on these matters largely because its permanent personnel force had earlier reached a stable and adequate operating level.

Training Activities

The Agency's training activities during the period stressed specialized seminars, graduate study, cooperative education, and apprentice training.

Specialized Seminars.—NASA continued its specially designed Agency-wide seminars to train its project and program management teams, and to promote management improvement and uniform treatment of Agency policy where required. Sixty-four seminars were held for 1049 people in the areas of procurement management, incentive contracting, contract administration, construction contract negotiation, and management information system.

Specialized Seminar for NASA Executives.—A six-hour executive course in "Contract Cost Management" was developed for NASA's top managers. This course provides a brief synthesis of current contract cost management concepts to senior NASA executives whose responsibilities do not permit participation in NASA's forty hour Contract Cost Management Course. The course also familiarizes these executives with the cost management techniques and tools being taught their subordinate staffs. Such familiarization enables these executives to evaluate the actual benefits of the forty hour course to the graduates and to the Agency.

Graduate Study.—Continued emphasis was placed on the development of NASA's available staff by further education through graduate study. In FY 1966, 2,687 employees took 4,174 graduate courses at 89 colleges and universities.

Cooperative Education.—The NASA cooperative education program is a work-study arrangement which provides undergraduate students with an opportunity to integrate academic study with planned related work experience at NASA installations. During FY 1966, 1,126 co-op students from 59 colleges and universities were employed. The FY 1967 program will be approximately the same size.

Apprentice Training.—The NASA Apprentice Training Program is designed to prepare, by organized on-the-job and classroom training, qualified persons to become journeymen and potential leaders in those skilled trades and subprofessional areas particularly applicable to NASA's research needs. During FY 1966, five field installations employed 550 apprentices, and the FY 1967 program will be approximately the same size.

Status of Personnel Force

These figures represent total employment (including temporaries) for the periods ending June 30, 1966, and December 31, 1966. Student employees returning to school in the fall accounted for the lower December figures.

	June 1966	*December 1966*
Headquarters	2336	2274
Ames Research Center	2310	2232
Electronics Research Center	555	619
Flight Research Center	662	618
Goddard Space Flight Center	3958	3791
Kennedy Space Center	2669	2618
Langley Research Center	4485	4296
Lewis Research Center	5047	4825
Manned Spacecraft Center	4889	4688

	June 1966	December 1966
Marshall Space Flight Center	7740	7434
NASA Pasadena Office	85	87
NASA Office, Downey	*	127
Space Nuclear Propulsion Office	115	114
Wallops Station	563	538
Western Support Office	294	105
TOTAL	35,708	34,366

*Included in WSO.

Key Executive Personnel Changes

NASA appointed two officials to its key executive staff during the period and reassigned two others. Three senior officials of the Agency resigned.

Key Appointments.—On November 1, General Jacob Edward Smart (USAF, Ret.) was appointed as a Special Assistant to the Administrator. (On January 1, 1967, he assumed the additional assignment of Acting Assistant Administrator for Administration.) Before his retirement on July 31, 1966, General Smart had completed assignments as Deputy Commander-in-Chief of the U.S. European Command, USAF Assistant Vice Chief of Staff, Vice Commander of the Tactical Air Force, and Commander-in-Chief, Pacific Air Force.

Bernhardt Louis Dorman was appointed (December 23) as Assistant Administrator for Industry Affairs (reporting for duty on January 16, 1967). Mr. Dorman came to NASA from the Aerojet General Corporation where he had served in a variety of key assignments including Head Test Engineer, Head of the corporate Long Range Planning Division, Vice President for Test Engineering, and Vice President for Future Operations.

Reassignments.—On October 1, James C. Elms was appointed Director, NASA Electronics Research Center, Cambridge, Massachusetts. He had served as Deputy Associate Administrator for Manned Space Flight from August 27, 1965. Previously, Mr. Elms had been Deputy Director of the NASA Manned Spacecraft Center, Houston, Texas (February 1963 to January 1964).

Earle J. Sample was appointed Director, NASA Pasadena Office (September 25), located at the Jet Propulsion Laboratory of the California Institute of Technology. Mr. Sample had been the Procurement and Contracting Officer of NASA's Western Support Office, Santa Monica, since January 1959.

Terminations.—Dr. Winston E. Kock resigned (September 30) as Director of the NASA Electronics Research Center. He had served in that capacity from September 1, 1964, coming to NASA from the Bendix Corporation.

On December 31, William B. Rieke resigned from the position

of Assistant Administrator for Industry Affairs, to which he had been appointed June 1, 1965. Mr. Rieke joined the staff of NASA in 1964 as Deputy Associate Administrator for Manned Space Flight. From May 30, 1966, Mr. Rieke had also been serving as Acting Assistant Administrator for Administration.

Walter D. Sohier resigned from the position of General Counsel of NASA on December 31. He joined on November 10, 1958, as Assistant General Counsel, became Deputy General Counsel in May, 1961, and General Counsel on December 8, 1963.

NASA Awards and Honors

Through the presentation of medals and top honor awards, NASA recognized both individual and group contributions to the space program. In all, during the period, 83 awards were presented.

The *Distinguished Public Service Medal* was awarded to Lloyd V. Berkner, Graduate Research Center of the Southwest, for outstanding and pioneering leadership in organizing and serving for four years as the Chairman of the Space Science Board of the National Academy of Sciences; for his wise counsel and vigorous efforts to bring government, universities, and industry into a new pattern of effective relationships to better serve the nation in the formative early years of the U.S. national effort in space research; for his vision in bringing our first non-military space project, Vanguard, into being; for his many contributions to both our national and international space programs and for his leadership in the development of new concepts and practices of graduate and postdoctoral education in space, earth, and life science research.

The *Distinguished Service Medal* was posthumously awarded to Hugh L. Dryden for his distinguished and pioneering scientific, engineering, and administrative leadership over a long and full life devoted to advancing the frontiers of research, particularly in aeronautical and space science; for his devotion and dedication to the expansion and practical use of man's knowledge; for his untiring leadership in our nation's efforts to further the manned as well as the unmanned exploration of outer space for peaceful purposes for the benefit of all mankind; and for providing a powerful personal example of the inspiration that flows from a deep personal commitment to the best of the spirit, the best of the mind, and a deep and abiding faith.

The *Distinguished Service Medal* was presented to T. Keith Glennan for his private and public dedication to advance the cooperation of education, industry, and government in the fields

of atomic energy, aeronautics, and space; and especially for the vision, courage, and competence which characterized his leadership as the first Administrator of NASA, during which he succeeded in setting America on the path to excellence in the exploration of space.

The *Distinguished Service Medal* was awarded to General Bernard A. Schriever (USAF, Ret.), for distinguished service to the United States, through his outstanding leadership of the Air Force Systems Command in a period when it was a most significant element in preserving the security of the nation and in which he and his associates in the Air Force significantly contributed to the successful accomplishment of the space research and development programs of the National Aeronautics and Space Administration.

The *Distinguished Service Medal* was awarded to George E. Mueller, Headquarters NASA, for his outstanding contributions to United States manned space flight as Director of the Gemini program in addition to directing the entire manned space flight program. His hard-driving leadership and complete dedication have provided motivation and inspiration to the whole government-industry space team. The success of the Gemini program testifies to the soundness of his judgment and the effectiveness of his management.

The *Distinguished Service Medal* was awarded to Charles W. Mathews, MSC, for outstanding contributions to United States manned space flight as Manager of the Gemini program. The achievement of the goals of the Gemini program is due, in large part, to his leadership and technical judgment in managing the planning and conduct of the program.

The *Exceptional Scientific Achievement* was presented to the following: Richard F. Arenstorf, MSFC; Helmut J. Horn, MSFC; Norman F. Ness, GSFC; George F. Pezdritz, LaRC; and James A. Chamberlin, MSC.

The *Outstanding Leadership Medal* was awarded to twelve individuals: John F. Clark, GSFC; Edgar M. Cortright, Hdqtr. OSSA; Robert L. Krieger, Wallops Station; George J. Vecchietti, Hdqtr.; Harold B. Finger, Hdqtr.; Harry H. Gorman, MSFC; Edmund F. O'Connor, MSFC; Eberhard F. M. Rees, MSFC; Herman K. Weidner, MSFC; Robert F. Thompson, MSC; John J. Williams, KSC; and Vincent G. Huston, USAF.

The *Exceptional Service Medal* was presented to 23 individuals: John W. Young, MSC; Michael Collins, MSC; Charles Conrad, Jr., MSC; Richard F. Gordon, Jr., MSC; M. Helen Davies, ARC;

Herbert A. Wilson, LaRC; Robert A. Rushworth, USAF; Roll D. Ginter, Headquarters; David S. Gabriel, LeRC; Edmund R. Jonash, LeRC; J. Cary Nettles, LeRC; Wilfred E. Scull, GSFC; Harry Press, GSFC; Leland F. Belew, MSFC; Lee B. James, MSFC; William G. Johnson, MSFC; Peter A. Minderman, KSC; James A. Lovell, Jr., MSC; Edwin E. Aldrin, MSC; John G. Albert, USAF; Ozro M. Covington, GSFC; John D. Hodge, MSC; and William B. Rieke, Headquarters.

The Public Service Award went to 18 individuals: Grant L. Hansen, General Dynamics Corp.; John F. Yardley, McDonnell Aircraft Corp.; Bastian Hello, Martin-Marietta Corp.; Bernhard A. Hohmann, Aerospace Corp.; Walter D. Smith, Martin-Marietta Corp.; Walter F. Burke, McDonnell Aircraft Corp.; Louis D. Wilson, Aerojet-General Corp.; Lawrence A. Smith, Lockheed-Missile & Space Co.; William B. Bergen, Martin-Marietta Corp.; Jack L. Bowers, General Dynamics Corp; George M. Bunker, Martin-Marietta Corp.; Paul T. Cooper, USAF; Daniel J. Haughton, Lockheed Aircraft Corp.; Roger Lewis, General Dynamics Corp.; James S. McDonnell, McDonnell Aircraft Corp.; R. I. McKenzie, Aerojet-General Corp.; L. Eugene Root, Lockheed Missile and Space Co.; and David S. Lewis, McDonnell Aircraft Corp.

Recipients of the *NASA Group Achievement Award* included Centaur Project Personnel, LeRC; Project Fire, LaRC; Pegasus Program, LaRC, Headquarters, and MSFC; Space Nuclear Propulsion Office, Headquarters; The Gemini Astronaut Team (MSC); The Manned Space Flight Network Team (GSFC); The Gemini Spacecraft Launch Team (KSC); Gemini Launch Operations and Range Support Team (USAF); The Gemini Program Office (MSC); The Gemini Program Office (NASA Hdqtr); and The Gemini Support Team (MSC).

INVENTIONS AND CONTRIBUTIONS BOARD

The Space Act provided for the establishment of the Inventions and Contributions Board with two assigned functions. One is to review petitions presented to NASA for waiver of rights to inventions made during the performance of NASA contracts and to recommend to the Administrator whether the waiver be granted or denied. The second function is to evaluate technical contributions submitted to NASA from any source and, if the Board determines a contribution is of significant value to aeronautical or space programs, to recommend to the Administrator that a monetary award be made. Appendix H lists the Board membership.

Patent Waiver Petitions Granted, Denied, or Action Deferred

During the period of this report, the Administrator granted 32 waivers of separately identified inventions and 38 blanket waivers of all inventions made during contract performance. Two petitions for waiver to separate inventions and 11 petitions for blanket waivers were denied.

In the case of 12 other petitions for blanket waivers made by companies with which a contract was being negotiated, the Board, because of lack of sufficient information, deferred its recommendation rather than delay placement of the contract. In addition, 4 petitions for waiver were reviewed by the Board, with final action pending. One petition for a blanket waiver to classified contract work was deferred. (See Appendix I.)

Contributions Awards

The Secretariat to the Board received 914 communications submitted as contributions, and it replied to each. Also, the Board evaluated in detail 62 additional contributions under Section 306 of the Space Act and made two awards totaling $2500. These awards are listed in Appendix J. The Board also evaluated 80 inventions made by NASA employees and made 80 monetary awards to 107 employees totaling $26,883. These awards are listed in Appendix K.

Two hearings on applications for awards were conducted. In neither case was an award recommended, and the Administrator made no awards.

ORGANIZATIONAL AND MANAGERIAL IMPROVEMENTS

Several organizational changes took place during the last half of 1966 to meet new or changing program requirements.

At *Manned Spacecraft Center*, a Science and Applications Directorate was established to reflect the growing significance of science and applications activities at that Center and to focus on those activities at a high level in the organization. The new Directorate combines within a single organization the scientific, management, and engineering skills needed to complete program planning and implementation in the science and applications areas.

As the Gemini Program began to phase out, planning was undertaken for the orderly transition of personnel. Priority requirements of other Manned Space Flight programs were analyzed and personnel from the Gemini Program were identified whose skills matched those requirements. More than 250 personnel were reassigned to the Apollo or Apollo Applications Program organiza-

tions where their special skills and previous experience can be fully utilized.

At *Marshall Space Flight Center,* a Saturn/Apollo Applications Program Office was established to manage the overall planning, coordination, and direction of alternate Apollo and follow-on activities assigned to that Center. The new Office represents MSFC to NASA Headquarters and other Centers in all matters pertaining to Apollo Applications. It is also responsible for program management of special hardware items being manufactured for the Apollo Applications Program.

Additionally, a Central Experiments Office was established at MSFC on the staff level of Research and Development Operations. This new Office will assist in identifying, defining, and developing the Center's in-flight experiments program and in managing the advanced and supporting research and technology program.

FINANCIAL MANAGEMENT

NASA completed and obtained Bureau of the Budget approval of a revised contractor financial reporting system and related system of special cost study reports. These were designed to provide project-oriented financial data originating in the contractors' records. The reports are used by installation project management in monitoring and applying resources to specific contracts, and by Headquarters in administering programs. They are also used as the basis for cost accruals, for budget and planning data, and for monthly project reporting to Headquarters.

A handbook covering the forms and instructions for reporting cost information was developed to guide contractors and was being published at the end of the year.

Basic planning and systems work was completed preparatory to converting Headquarters accounting and reporting to a real-time basis. Space and personnel requirements were defined, and training plans were initiated to provide for a smooth change-over when the necessary equipment is received and machine programs are developed and tested. When this real-time system becomes operative, it should provide for immediate updating of records; for minimal recordkeeping, input preparation, and reconcilement; for prompt financial status information through remote inquiry stations; and for improved special and recurring reports.

Fiscal Year 1968 Program

Table 1 shows the planned level of effort in research and development, construction of facilities, and administrative operations for fiscal year 1968.

Financial Reports, December 31, 1966

Table 2 shows fund obligations and accrued costs incurred during the six months ended December 31, 1966. Appended to the table is a summary by appropriation showing current availability, obligations against this availability, and unobligated balances as of December 31, 1966.

Table 3 shows NASA's consolidated balance sheet as of December 31, 1966, as compared to that of June 30, 1966. Table 4 summarizes the sources and applications of NASA's resources during the six months ended December 31, 1966. Table 5 provides an analysis of the net change in working capital disclosed in Table 4.

Table 1.—NASA Budget Estimates Fiscal Year 1968

(In thousands)

Research and development:	
Apollo	$2,546,500
Apollo applications	454,700
Advanced mission studies	8,000
Physics and astronomy	147,500
Lunar and planetary exploration	142,000
Voyager	71,500
Sustaining university program	20,000
Launch vehicle procurement	165,100
Bioscience	44,300
Space applications	104,200
Basic research	23,500
Space vehicle systems	37,000
Electronics systems	40,200
Human factors systems	21,000
Space power and electric propulsion systems	45,000
Nuclear rockets	74,000
Chemical propulsion	38,000
Aeronautics	66,800
Tracking and data acquisition	297,700
Technology utilization	5,000
Total, research and development	4,352,000
Construction of facilities	76,700
Administrative operations	671,300
Total	$5,100,000

Table 2—Status of Appropriations as of December 31, 1966
(In thousands)

Appropriations	*Six Months Ended December 31, 1966* Obligations	Accrued Costs
Research and development:		
Gemini	$ 44,078	$ 80,564
Apollo	1,904,109	1,565,920
Advanced manned missions	3,354	5,282
Apollo applications	12,378	8,192
Completed missions	(23)	(27)
Physics and astronomy	68,732	54,215
Lunar and planetary exploration	119,171	113,657
Sustaining university program	5,482	16,530
Launch vehicle development	11,830	19,818
Launch vehicle procurement (unmanned)	54,494	80,413
Bioscience	20,628	19,961
Meteorological satellites	24,263	21,104
Communications and applications technology satellites	22,824	17,310
Mission analysis program	1,211	630
Basic research program	11,403	9,539
Space vehicle systems	11,959	12,207
Electronics systems	10,093	13,695
Human factors systems	6,234	5,124
Nuclear rockets	27,138	29,236
Chemical propulsion	20,052	24,412
Space power and electric propulsion systems	17,761	20,323
Aeronautics	16,677	11,610
Tracking and data acquisition	152,180	142,379
Technology utilization	1,512	2,317
Operations	(6)	(5)
Reimbursable	30,112	38,934
Total, research and development	2,597,646	2,313,340
Construction of facilities	66,764	130,004
Administrative operations	340,807	323,700
Totals	$3,005,217	$2,767,044

Appropriation Summary	*Current Availability* [1]	*Total Obligations*	*Unobligated Balance*
Research and development	$4,538,765	$2,597,646	$1,941,119
Construction of facilities	213,103	66,764	146,339
Administrative operations	649,783	340,807	308,976
Totals	$5,401,651	$3,005,217	$2,396,434

[1] The availability listed includes authority for anticipated reimbursable orders.

THE NASA COST REDUCTION PROGRAM

The NASA Cost Reduction Program encourages the achievement of economy and efficiency in the operations of the Agency's installations and contractors, stimulates cost-conscious and innovative attitudes among NASA's own employees and those of

Table 3—NASA Comparative Consolidated Balance Sheet
December 31, 1966 and June 30, 1966
(In millions)

Assets	*Dec. 31, 1966*	*June 30, 1966*
Cash:		
Funds with U.S. Treasury	$4,703.7	$2,592.9
Accounts receivable:		
Federal agencies	36.1	24.1
Other	.8	1.5
	36.9	25.6
Inventories		
NASA-held	32.7	35.3
Contractor-held	134.9	114.8
	167.6	150.1
Advances and prepayments:		
Federal agencies	6.9	6.8
Deposits on returnable containers	.1	----
Other	33.9	24.3
	40.9	31.1
Fixed assets:		
NASA-held	2,167.8	1,990.7
Contractor-held	518.7	485.3
Construction in progress	1,148.0	1,176.4
	3,834.5	3,652.4
Total assets	$8,783.6	$6,452.1
Liabilities and Equity		
Liabilities:		
Accounts payable:		
Federal agencies	$ 219.2	$ 215.6
Other	624.1	737.4
	843.3	953.0
Accrued annual leave	32.7	32.7
Total liabilities	876.0	985.7
Equity:		
Net investment	3,170.7	2,849.1
Undisbursed allotments	3,495.7	2,621.4
Unapportioned and unallotted appropriation	1,397.5	79.5
	8,063.9	5,550.0
Less reimbursable disbursing authority uncollected	(156.3)	(83.6)
Total equity	7,907.6	5,466.4
Total liabilities and equity	$8,783.6	$6,452.1

Table 4—Resources Provided and Applied Six Months Ended December 31, 1966

(In millions)

Resources Provided			
Appropriations:			
Research and development	-------	-------	$4,235.1
Construction of facilities	-------	-------	85.0
Administrative operations	-------	-------	647.5
Total appropriations	-------	-------	4,967.6
Revenues	-------	-------	41.8
Total resources provided	-------	-------	$5,009.4

Resources Applied	*Total Costs Six Months Ended Dec. 31, 1966 1966*	*Less Costs Applied to Assets*	
Operating costs:			
Research and development	$2,313.3	$ 81.8	$2,231.5
Construction of facilities	130.0	130.0	-------
Administrative operations	323.7	5.3	318.4
	$2,767.0	$ 217.1	-------
Total operating costs	-------	-------	2,549.9
Increase in fixed assets:			
NASA-held	-------	-------	177.1
Contractor-held	-------	-------	33.4
Construction in progress	-------	-------	(28.4)
Total increase in fixed assets	-------	-------	182.1
Property transfers and retirements-net	-------	-------	18.3
Increase in working capital (Table 5)	-------	-------	2,259.1
Total resources applied	-------	-------	$5,009.4

Table 5—Net Change in Working Capital Six Months Ended December 31, 1966

(In millions)

	Dec. 31, 1966	*June 30, 1966*	*Increase*
Current assets:			
Funds with U.S. Treasury	$4,703.7	$2,592.9	$2,110.8
Accounts receivable	36.9	25.6	11.3
Inventories	167.6	150.1	17.5
Advances and prepayments	40.9	31.1	9.8
Total current assets	4,949.1	2,799.7	2,149.4
Current liabilities:			
Accounts payable	843.3	953.0	109.7
Working capital	$4,105.8	$1,846.7	-------
Increase in working capital	-------	-------	$2,259.1

its contractors; and fosters the dissemination of cost reduction techniques which have the potential for wider application. The program emphasizes that efficiencies and economies are to be effected without compromising performance, reliability, or schedule.

The cost reduction goal which NASA set for its internal operations during FY 1967 is $175,000,000. This goal is over and above any savings which may be accomplished by NASA's contractors under the NASA-Contractor Cost Reduction Program. Through December 31, 1966, savings which have been reported against this goal and accepted as meeting NASA's criteria, amount to $69,000,595. During this same period, NASA's principal contractors reported savings of $119,434,900 attributable to NASA work in their plants.

PROCUREMENT AND SUPPLY MANAGEMENT

In an effort to improve its procurement management, NASA established certain new policies and procedures, acted to further implement others, and give increased emphasis to its incentive contracting practices.

Procurement Policies and Procedures

NASA issued a new procurement directive relating to patents and patent infringements, took additional steps to broaden geographic participation in the aerospace program, and continued its efforts to strengthen procurement management through specially designed surveys.

Procurement of Items Involving Likely Patent Infrigement.—In a new procurement directive, NASA has adopted a policy whereby it would become a licensee under a privately owned patent in appropriate instances prior to the patented items. Under such a procedure, a definite royalty would be established which NASA would be obligated to pay to the patent owner if the patented items were procured from someone other than the patent owner or his licensees. This would put NASA in a position to determine with certainty which of the competing bids or proposals would be most advantageous to NASA, price and other factors considered. (This determination would be reached by adding the royalty to the price offered by unlicensed suppliers.) Thus, if an award were made to an unlicensed supplier, the royalty would be paid by NASA to the patent owner under the license agreement, and if award were made to the patent owner or his licensee, no royalty would be paid since procurement would be from a licensed source. The important advantage of

this procedure would be that there could be no subsequent claim or suit for patent infringement against the Government since the procurement, regardless of its source, would be licensed.

Under this policy, NASA may enter into a license agreement with the patent holder for the procurement involved, provided that the patent owner gives timely notice that the procurement will infringe his patent; that NASA patent counsel determines that the procurement will infringe the patent and that the patent has been upheld by a court or has found commercial acceptance; that the patent owner is willing to license NASA at a rate no higher than its lowest rate to a private concern; and that the contracting officer determines that entering into the license agreement will not unduly delay the procurement.

Under 28 U.S.C. 1498, Government contractors and subcontractors are authorized to infringe patents when manufacturing items pursuant to Government contracts. In such cases, the statute provides that the patent holder's exclusive remedy is a suit against the United States in the Court of Claims for damages. Pursuant to 42 U.S.C. 2473(b)(3), as implemented by NASA PR9.106, a patent holder may seek administrative relief from NASA for patent infringement.

NASA, in letters to the Comptroller General (dated June 13 and July 14, 1966), pointed out that as a practical matter 28 U.S.C. 1498 has not always afforded adequate and effective relief to the patent holder. Further, while administrative relief is available to the patent owner, its exercise often results in higher overall costs to NASA (when for instance, the amount of settlement is added to the cost of the purchase from the unlicensed source). Finally, it was concluded that by permitting unlicensed sources to freely use patents under Government contracts, privately financed research in technical fields of interest to NASA is discouraged with the Government being the ultimate loser.

To remedy this situation, the new procedure was developed and approved by the Comptroller General for use on a trial basis.

Geographic Participation in the Aerospace Program.—NASA developed and issued a contract clause to be used in all research and development contracts of $500,000 and over and in subcontracts of $100,000 and over. The clause states NASA's policy to have all geographic regions participate in filling the scientific, technical, research and development, and other needs of the aerospace program. The clause requires contractors to solicit subcontract sources on the broadest feasible geographic basis, con-

sistent with efficient contract performance, and without impairing program effectiveness or increasing program cost. The policy and the implementing contract clause support the intent of the Congress in fostering national economic goals, as expressed in the 1966 and 1967 NASA Authorization Acts (Public Laws 89–53 and 89–528).

Procurement Management Surveys.—To improve the effectiveness of its procurement management efforts, NASA earlier established the Procurement Surveys Division. The mission of this division is to develop, manage, and carry out an effective survey program aimed at assuring compliance with NASA procurement policies and at developing improvements in procurement operations. The professional procurement personnel within this division form the basic survey teams which are augmented as required by competent personnel from other staff offices within the Procurement Office.

The Surveys Division completed four surveys during the period, and these proved to be quite beneficial. They provided managers at all levels an objective evaluation of procurement effectiveness at buying activities. Through these surveys a test of the effectiveness of existing procurement policies and procedures is determined and an analysis is made of where and to what extent new or revised procurement policies are required. Local problems are identified and recommendations for improvement are made. In addition, innovative techniques developed by the various activities are reviewed for possible NASA-wide application.

Annual Procurement Conference

The annual procurement conference was held in November and attended by NASA Procurement Officers from each of the buying installations as well as by representatives from other staff and program offices. Problem areas requiring new procedures or policies to improve procurement management were discussed at the conference. Responsibility for further study of these problems was assigned to individual centers, and the findings and recommendations will be submitted to NASA Headquarters for final action.

These annual conferences have proved to be very beneficial. They provide a forum for the discussion of the more significant procurement problems and an opportunity for an exchange of information among the various procurement organizations.

Incentive Contracting

During this reporting period, NASA initiated or expanded

several programs designed to improve incentive contract structuring and performance. Additionally, the procurement office sponsored a NASA/DOD incentive contracting workshop during August to study newly developed incentive evaluation techniques. This workshop and follow-on sessions should transform contracting innovations into workable and efficient practices.

The Agency's contract-data reporting procedures were updated to provide additional narrative and statistical information on progress and potential problems on incentive contracts. Revised reporting instructions, completed, should generate the information necessary for the control and timely definitization of contract changes.

In addition, the Agency intensified the review of incentive contracts both in the prenegotiation objective stage and in the preaward stage. These reviews are making substantial contributions to proposed incentive arrangements before negotiation.

Summary of Contract Awards

NASA's procurement for the first 6 months of Fiscal Year (FY) (this report period) totaled $2,785 million. This is $6 million more than was awarded during the corresponding period of FY 1966. Approximately 85 percent of the net dollar value was placed directly with business firms, 2 percent with educational and other nonprofit institutions, 5 percent with the California Institute of Technology for operation of the Jet Propulsion Laboratory, 7 percent with or through other Government agencies, and 1 percent outside the United States.

Contracts Awarded to Private Industry

Ninety percent of the dollar value of procurement requests placed by NASA with other Government agencies resulted in contracts with industry awarded by those agencies on behalf of NASA. In addition, about 77 percent of the funds placed by NASA under the Jet Propulsion Laboratory contract resulted in subcontracts or purchases with business firms. In short, about 95 percent of NASA's procurement dollars was contracted to private industry.

Seventy-two percent of the total direct awards to business represented competitive procurements, either through formal advertising or competitive negotiation. An additional 9 percent represented actions on follow-on contracts placed with companies that had previously been selected on a competitive basis to perform the research and development on the applicable project. In these instances, selection of another source would

have resulted in additional cost to the Government by reason of duplicate preparation and investment. The remaining 19 percent included contracts for facilities required at contractor's plants for performance of their NASA research and development effort, contracts arising from unsolicited proposals offering new ideas and concepts, contracts employing unique capabilities, and procurements of sole-source items.

Small business firms received $92 million, or 4 percent of NASA's direct awards to business. However, most of the awards to business were for large continuing research and development contracts for major systems and major items of hardware. These are generally beyond the capability of small business firms on a prime contract basis. Of the $282 million of new contracts of $25,000 and over awarded to business during the six months, small business received $32 million, or 11 percent.

In addition to the direct awards, small business received substantial subcontract awards from 83 of NASA's prime contractors participating in its Small Business Subcontracting Program. Total direct awards plus known subcontract awards aggregated $284 million, or 12 percent of NASA's total wards to business during the first half of FY 1967.

Geographical Distribution of Prime Contracts

Within the United States, NASA's prime contract awards were distributed among 44 States and the District of Columbia. Business firms in 43 States and the District of Columbia, and educational institutions and other nonprofit institutions in 41 States and the District of Columbia, participated in the awards. Two percent of the awards went to labor surplus areas located in 13 States.

Subcontracting

Subcontracting effected a further distribution of the prime contract awards. NASA's major prime contractors located in 26 States and the District of Columbia reported that their larger subcontract awards on NASA effort had gone to 1,215 subcontractors in 42 States and the District of Columbia, and that 65 percent of these subcontract dollars had crossed state lines.

Major Contract Awards

Among the major research and development contract awards by NASA during the period were the following:

(1) Grumman Aircraft Engineering Corp., Bethpage, N.Y. NAS 9–1100. Lunar module development for the Apollo program. Awarded $344 million; cumulative awards $1,102 million.

(2) North American Aviation, Inc., Downey, Calif. NAS 9–150. Design, develop and test three-man earth to moon and return Apollo spacecraft. Awarded $338 million; cumulative awards $2,411 million.

(3) North American Aviation, Inc., Downey, Calif. NAS 7–200. Design, develop, fabricate and test the S–II stage of the Saturn V vehicle and provide launch support services. Awarded $181 million; cumulative awards $859 million.

(4) The Boeing Company, New Orleans, La. NAS 8–5608. Design, develop and fabricate the S–IC stage of the Saturn V vehicle, construct facilities in support of the S–IC stage and provide launch support services. Awarded $171 million; cumulative awards $904 million.

(5) Douglas Aircraft Company, Inc., Santa Monica, Calif. NAS 7–101. Design, develop and fabricate the S–IV B stage of the Saturn V vehicle and associated ground support equipment and provide launch support services. Awarded $127 million; cumulative awards $726 million.

(6) General Electric Company, Daytona Beach, Fla. NASW –410. Overall integration, checkout and reliability of Apollo space vehicle system. Awarded $76 million; cumulative awards $488 million.

(7) North American Aviation, Inc., Canoga Park, Calif. NAS 8–19. Develop and procure 200,000—pound thrust J–2 rocket engine with supporting services and hardware. Awarded $75 million; cumulative awards $497 million.

(8) International Business Machines Corp., Rockville, Md. NAS 8–14000. Fabrication, assembly and checkout of instrument units for Saturn IB and V vehicles. Awarded $65 million; cumulative awards $158 million.

(9) Chrysler Corporation, New Orleans, La. NAS 8–4016. Fabricate, assemble, checkout and static test Saturn S–I stage; provide product improvement program and space parts support; modify areas of Michoud Plant assigned to contractor; provide launch support services. Awarded $51 million; cumulative awards $371 million.

(10) General Motors Corp., Milwaukee, Wisc. NAS 9–497. Guidance computer subsystem for Apollo command service module. Awarded $50 million; cumulative awards $280 million.

(11) International Business Machines Corp., Bethesda, Md. NAS 9–996. Design, develop and implement real time computer

complex for Integrated Mission Control Center at the Manned Spacecraft Center. Awarded $38 million; cumulative awards $74 million.

(12) North American Aviation, Inc., Canoga Park, Calif. NAS 8–18734. Fabrication and delivery of F–1 engines; provide supporting services and hardware. Awarded $36 million; (new contract).

(13) North American Aviation, Inc., Canoga Park, Calif. NAS 8–5604. Fabrication and delivery of F–1 engines; provide supporting services and hardware. Awarded $30 million; cumulative awards $217 million.

(14) Aerojet General Corp., Azusa, Calif. SNP–1. Design, develop, and produce a nuclear powered rocket engine (NERVA). Awarded $28 million; cumulative awards $359 million.

(15) Bendix Corporation, Owings Mills, Md. NAS 5–9870. Operation, maintenance and support services for the Manned Space Flight Network. Awarded $21 million; cumulative awards $46 million.

(16) General Dynamics Corp., San Diego, Calif. NAS 3–8700. Fabrication and delivery of Centaur vehicles and flight support units. Awarded $16 million; (new contract).

(17) Bendix Corporation, Teterboro, N.J. NAS 8–13005. Stabilized platform systems and associated hardware for Saturn IB and Saturn V vehicles. Awarded $16 million; cumulative awards $43 million.

(18) The Boeing Company, Seattle, Wash. NAS 1–3800. Develop and fabricate lunar orbiter spacecraft systems. Awarded $14 million; cumulative awards $137 million.

(19) Trans World Airlines, Inc., New York, N.Y. NAS 10–1242. Provide base support services at Kennedy Space Center. Awarded $14 million; cumulative awards $46 million.

(20) Hughes Aircraft Co., Culver City, Calif. NAS 5–3823. Develop and test advanced technological spacecraft. Awarded $14 million; cumulative awards $53 million.

Major Contractors

The 25 contractors receiving the largest direct awards (net value) were as follows:

	Contractor & place of contract performance	*Net value of awards (Thousands)*
1.	North American Aviation, Inc., Downey, Calif.*	$682,793
2.	Grumman Aircraft Engineering Corp., Bethpage, N. Y.	356,755
3.	Boeing Company, New Orleans, La.*	187,937
4.	Douglas Aircraft Co., Inc., Santa Monica, Calif.*	138,977
5.	International Business Machines Corp., Huntsville, Ala.*	130,536
6.	General Electric Company, Huntsville, Ala.*	104,571
7.	Bendix Corp., Owings Mills, Md.*	71,017
8.	Chrysler Corp., New Orleans, La.*	51,553
9.	General Motors Corp., Milwaukee, Wisc.*	50,115
10.	Aerojet-General Corp., Sacramento, Calif.*	42,020
11.	Radio Corporation of America, Camden, N. J.*	30,119
12.	Lockheed Aircraft Corp., Houston, Texas*	24,017
13.	General Dynamics Corp., San Diego, Calif.*	24,012
14.	TRW, Inc., Houston, Texas*	23,813
15.	Sperry Rand Corp., Huntsville, Ala.*	22,949
16.	LTV Aerospace Corp., Dallas, Texas*	21,148
17.	Philco Ford Corp., Houston, Texas*	17,694
18.	Hughes Aircraft Co., Culver City, Calif.*	17,620
19.	United Aircraft Corp., West Palm Beach, Fla.*	16,102
20.	General Precision, Inc., Houston, Texas*	15,418
21.	Trans World Airlines, Inc., Kennedy Space Center, Fla.	14,079
22.	Honeywell, Inc., Framingham, Mass.*	10,758
23.	Federal Electric Corp., Kennedy Space Center, Fla.*	9,988
24.	Union Carbide Corp., Sacramento, Calif.*	7,877
25.	Air Products & Chemicals, Inc., Long Beach, Calif.*	7,860

* Awards during year represents awards on several contracts which have different principal places of performance. The place shown is that which has the largest amount of the awards.

LABOR RELATIONS

Time lost due to strikes on NASA construction projects was reduced to 18,243 man days during the last half of 1966, compared to 22,941 days lost during the last half of 1965.

However, the most dramatic development appeared at the John F. Kennedy Space Center and Cape Kennedy, where all projects have been completely free from strike activity since September 8, 1966. This KSC all-time record for labor relations stability continues through the present time.

For the entire calendar year 1966 man days lost totalled 30,210 compared to 67,815 days in calendar year 1965. These figures involve construction projects only, since lost time due to strikes on other projects was relatively small.

At the end of this period, the NASA Office of Labor Relations was engaged in increased planning for preventive labor relations programs at all centers, particularly those under the Office of Manned Space Flight.

FACILITIES MANAGEMENT

Through its facilities management program, NASA published policies, criteria, and operational practices in managing agency-controlled facilities and real property. It also assisted field centers in establishing sound facilities management programs.

An inventory of NASA' technical facility capability was made and was being cataloged for effective use. This data will provide a compatible standardized system of information covering the capabilities and functions of NASA-owned or controlled research, development, and test facilities at Agency installations.

Facilities, maintenance, repair, and operation costs information was gathered, and an intensified management engineering effort was being directed toward the reduction of future costs of maintenance, repair, and operation of NASA's $2.6 billion worth of real property.

With the assistance of the Corps of Engineers, NASA completed a study of the status of the fire prevention programs for the facilities at three field centers. This project brought to management's attention certain fire hazards. Projects to develop preventive methods and install equipment in the facilities were initiated and funds made available. Plans called for extending this study to other centers.

RELATIONSHIPS WITH OTHER GOVERNMENT AGENCIES

NASA continued maintaining close coordination with other government agencies having an interest in aeronautics and space. This coordination is accomplished by direct and frequent contacts of personnel at all levels, through formal organizations such as the NASA-DOD Aeronautics and Astronautics Coordinating Board, and through ad hoc groups and advisory boards. The Aeronautics and Astronautics Coordinating Board (AACB) continued as the principal medium for the coordination of the space and aeronautics programs of NASA and DOD.

During the period, the annual joint review of planned construction or expansion of DOD and NASA aeronautical and space facilities in FY 68 was initiated. The purpose of this review is to eliminate unwarranted duplication. The joint NASA-DOD study of possible missions and concepts for reusable launch vehicles and hypersonic propulsion continued. Pertinent cost-effectiveness studies previously conducted by industry and government were reviewed.

The Supporting Space Research and Technology Panel and the Launch Vehicle Panel of the AACB completed their reviews of advanced space propulsion systems. The advanced cryogenic rocket engine programs of NASA and the DOD were reoriented

to develop and demonstrate two concepts at a common thrust level. In order to preserve a capability in large solid motor technology, the two agencies continued to conduct level-of-effort programs that supplement each other. Also, the continuation of the long-life space power systems was endorsed, with special emphasis on further development of the SNAP–8 system.

NASA and DOD completed plans to provide for the efficient use of secondary payload space on their launch vehicles and spacecraft. Catalogs advertising payload space on forthcoming space missions were published and distributed by both agencies.

A NASA-DOD ad hoc committee initiated a study of security classification practices in the two agencies. This study will include a review of security policies related to the areas of guidance, airborne photographic cameras, and hypersonic propulsion.

The space science programs of NASA and the DOD were coordinated to provide a better understanding of each other's programs and to eliminate unwarranted duplication.

The Joint Navigation Satellite Committee Report, setting forth national requirements, future guidelines, relative costs, and technical merits of navigational satellite systems, was accepted by all member agencies (NASA, DOD, FAA, Commerce, and Treasury).

The Manned Space Flight Policy Committee developed NASA-DOD guidelines for the conduct of the NASA earth resources survey program. Also, the Committee was continuing a cost-effectiveness study of the Titan IIIC and the Uprated Saturn I launch vehicles.

Arrangements were made for NASA to assist the Air Force Systems Command in its study of Fundamental Space Principles, Applications, and Doctrine (Project SPAD) by furnishing copies of reports on appropriate NASA studies of future space systems and providing informal consultative assistance to the AFSC Planning Group.

In the application of the Agency's Technology Utilization Program, the needs of the Department of Defense were analyzed to make sure that information and innovations in all areas of space technology (materials, propulsion, electronics, power sources fuels, and the like) of potential value to DOD, are made available.

The exchange of military and civilian personnel between NASA and the Department of Defense continued. Several NASA employees were detailed for tours of duty with the Air Force Systems Command and with the Naval Material Command in connection with the MOL and other programs.

Following the recent passage of the Marine Resources and Engineering Development Act, the Administrator of NASA was designated as an observer on the National Council on Marine Resources and Engineering Development. NASA participation in the Council and in the activities of the Interagency Committee on Oceanography will make it easier to apply space technology to the National Oceanographic Program.

Close cooperation between NASA and the DOD in aeronautical research continued. The objectives of these efforts were to validate theory and wind tunnel data and to obtain information on design, materials, and operational techniques applicable to future supersonic military and transport aircraft. Fourteen aircraft on loan from the Armed Forces were being used as research and testbed vehicles at NASA Research Centers. The DOD increased its use of NASA wind tunnels.

Other agreements entered into during the period with the Department of Defense or one of the individual Military Services related to contract administration services, operation of the Bermuda Tracking Station, Air Force support of the Biosatellite Project, procedures for the funding and operation of Apollo Range Ships and Instrumentation Aircraft, the loan of research aircraft, and the joint investigation of space program accidents.

Appendix A

Congressional Committees on Aeronautics and Space

(July 1–December 31, 1966)

Senate Committee on Aeronautical and Space Sciences

CLINTON P. ANDERSON, New Mexico, *Chairman*
RICHARD B. RUSSELL, Georgia
WARREN G. MAGNUSON, Washington
STUART SYMINGTON, Missouri
JOHN STENNIS, Mississippi
STEPHEN M. YOUNG, Ohio
THOMAS J. DODD, Connecticut
HOWARD W. CANNON, Nevada
SPESSARD L. HOLLAND, Florida
WALTER F. MONDALE, Minnesota
HARRY F. BYRD, JR., Virginia
MARGARET CHASE SMITH, Maine
BOURKE B. HICKENLOOPER, Iowa
CARL T. CURTIS, Nebraska
LEN B. JORDAN, Idaho
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Appendix C

Current Official Mailing Addresses for Field Installations

(December 31, 1966)

Installation and telephone number	Official	Address
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Electronics Research Center; 617-491-1500.	Mr. James C. Elms, Director.	575 Technology Square, Cambridge, Mass. 02139.
Flight Research Center; 805-258-3311.	Mr. Paul F. Bikle, Director	P.O. Box 273, Edwards, Calif. 93523.
Goddard Space Flight Center; 301-474-9000.	Dr. John F. Clark, Director	Greenbelt, Md. 20771.
Goddard Institute for Space Studies; 212-UN6-3600.	Dr. Robert Jastrow, Director.	2880 Broadway, New York, N.Y. 10025.
Jet Propulsion Laboratory; 213-354-4321.	Dr. Wm. H. Pickering, Director.	4800 Oak Grove Drive, Pasadena, Calif. 91103.
John F. Kennedy Space Center; 305-867-7110.	Dr. Kurt H. Debus, Director.	Kennedy Space Center, Fla. 32899.
Langley Research Center; 703-722-7961.	Dr. Floyd L. Thompson, Director.	Langley Station, Hampton, Va. 23365.
Lewis Research Center; 216-433-4000.	Dr. Abe Silverstein, Director.	21000 Brookpark Rd., Cleveland, Ohio 44135.
Manned Spacecraft Center; 713-HU3-0123.	Dr. Robert L. Gilruth, Director.	Houston, Texas 77058.
George C. Marshall Space Flight Center; 205-877-1100.	Dr. Wernher von Braun, Director.	Huntsville, Ala., 35812.
Michoud Assembly Facility; 504-255-3311.	Dr. George N. Constan, Manager.	P.O. Box 29300, New Orleans, La. 70129.
Mississippi Test Facility; 601-688-2211.	Mr. Jackson M. Balch, Manager.	Bay St. Louis, Miss. 39520.
KSC Western Test Range Operations Division; 805-866-1611.	Mr. Joseph B. Schwartz, Acting Director.	P.O. Box 425, Lompac, Calif. 93436.
Pasadena Office; 213-354-5359	Mr. Earl J. Sample, Director.	4800 Oak Grove Dr., Pasadena, Calif. 91103.
Plum Brook Station; 419-625-1123.	Mr. Alan D. Johnson, Director.	Sandusky, Ohio 44871.
Wallops Station; 703-VA4-3411	Mr. Robert L. Krieger, Director.	Wallops Island, Va. 23337.
Western Support Office; 213-451-7411.	Mr. Robert W. Kamm, Director.	150 Pico Blvd., Santa Monica, Calif. 90406.

Appendix D

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(Telephone Information: 963–7101)

Appendix E

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(December 31, 1966)

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Appendix F

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(December 31, 1966)

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Appendix H

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(December 31, 1966)

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Appendix I

Patent Waivers Granted and Denied by NASA Upon Recommendation of the Agency's Inventions and Contributions Board

(July 1—December 31, 1966)

Invention	Petitioner	Action on Petition
Circulating Page Computer	Dr. Mario R. Shaffner (Harvard College Observatory).	Granted.
Chemisorption Detector for Hydrogen	University of Arizona	Do.
Chemisorption Detector for Water Vapor	University of Arizona	Do.
Field Ionization Detector for Water Vapor	University of Arizona	Do.
Filter Element	California Institute of Technology.	Do.
Method of Synchronizing Telemetry Channels	California Institute of Technology.	Do.
Bakable, Metal, Mercury Diffusion Pump	GCA Corp., GCS Tech. Div.	Do.
Metal, Non-level Sensitive Cold Trap	GCA Corp., GCS Tech. Div.	Do.
Laminated Gasket Materials for Liquid Oxygen Svc.	Whittaker Corp.	Do.
Method and Apparatus for Erasing	Leland Standford Junior Univ.	Do.
Adjustable Tension Wire Guides	General Motors Corp.	Denied.
cd se-an se Thin Film Rectifier	Melpar, Inc.	Granted.
Relief Seal with Duel Sliding Surfaces	North American Aviation, Inc.	Do.
Improved Preparation of Chlorinated Aromatic Polyisofyanates.	Whittaker Corp.	Do.
Hexafluoropentane Diamine	do	Do.
Flourine Containing Polyformals	Whittaker Corp.	Granted.
Process for the Preparation of Trtrafluoro- p-phoenylenodiamine.	do	Do.
Perfluorotrimethylene Diisocyanate	do	Do.
Tetrafluoro-p-phenylene Diisocyanate	do	Do.
1,5,-Dichloro-2,2,3,3,4,4,-Hexafluoropentane	do	Do.
Complementary Transistors Structure and Method of Making Same.	Westinghouse Electric Corp.	Do.
Silver 15 Zinc Brazing Alloy	North American Aviation, Inc.	Do.
Plasma Accelerator Using Hall Currents	Electro-Optical Systems, Inc.	Do.
Thin Film Ferrites	Melpar, Inc.	Do.
Electronic Divider Multiplier	Beckman Instruments	Denied
Thermal Radiative Flux Gauge	The Air Preheater Co.	Granted.
Insertion Tool and Follower	Douglas Aircraft Co., Inc.	Granted.
Heat Pump	Mansanto Chemical Corp.	Do.
Polydiene Cyclized Polybutadiene Urethanes Methods of Manufacture and Uses.	TRW, Inc.	Do.
Charged Particle Focal Point Locator and Automatic Electron Beam Focal Point Locator.	General Electric Company	Do.
Electronic Circuit Limit	Douglas Aircraft Co., Inc.	Do.
Bandwidth Compression Technique	Stanford Research Institute	Do.
Electron Beam Welding Standby Absorbing System.	General Electric Co.	Do.
Utilizing Bibulous Material Wick Means to Feed Electrolyte by Capillary Action.	Electric Storage Battery Co.	Do.

Patent Waivers Granted and Denied by NASA Upon Recommendation of the Agency's Inventions and Contributions Board—Continued

Contract Work [1]	Petitioner	Action on Petition
Design of a Load Relief Control System	Honeywell, Inc.	Granted
Development of High Performance Light Weight Electrodes for Hydrogen-Oxygen Cells.	American Cyanamid Co.	Do.
Development of Forgable, High Temperature Chromium-base Alloys.	General Electric Co.	Denied
To Define Lunar Environmental Effects on ATS Scientific Instruments.	Hughes Aircraft Co., Inc.	Do.
Linear Accelerometer Design Study	Sanders Associates, Inc.	Granted
Custom Fabrication of a Constant Bandwidth Double Side Band and A-M Telemetry System.	Dynatronics, Inc.	Do.
Design Study of Turbine Stator-Combustor Integration in Turbine Engines.	Curtiss-Wright Corp.	Denied
Study and Investigation of Providing a Transducer with a Direct Digital Output.	Dynamics Research Corp.	Granted
Design and Development of Apparatus for an Arc Welding Device.	Air Reduction Co., Inc.	Do.
Development of Satellite Tracking System	General Dynamics/Electronics.	Do.
Design, Development Fabrication and Delivery of Improved MOS Transistors.	Philco Corp., Lansdale Division.	Denied
Addressable Time Division System	Martin Company	Denied
Develop Compressor End Seals, Stator Interstage Seals and Pivot Seals in Advanced Air Breathing Propulsion Systems.	United Aircraft Corp.	Denied
Development of Mainshaft Seals for Advanced Air Breathing Propulsion Systems.	do	Do.
Experimental Evaluation of Advanced Compressor Concepts.	do	Do.
Feasibility Study Covering Diffraction Limited Optics for Space Applications.	Perkin-Elmer Corp.	Granted
Study of Electrolytes, Electrodes and Cell Systems.	Livingston Electronic Corp.	Do.
R&D of Contamination Systems and Develop New Fluids and Methods for Flushing Propellant Systems.	Dow Chemical Co.	Do.
Study of Abrasives Techniques for Lunar and Planetary Geological and Biological Surface and Subsurface Sampling.	National Research Corp.	Do.
Study of Component Parts of Fuel Cell Systems	Livingston Electronic Corp.	Do.
Design, Develop and Fabricate Optical Modulators.	Sylvania Electronic Systems	Do.
Examination of Electrophilic Behavior of Electronegative Materials at Various Temperature and Pressure.	Franklin GNO Corp.	Denied
Development of a Fluid Transpiration Arc	Vitro Corp. of America	Do.
Design, Development and Fabrication of a Digital Controller for Spacecraft.	Honeywell, Inc.	Granted
R&D Prototype Highpower Single Frequency Output Continuous Wage Laser System.	Sylvanic Electronic Systems	Granted
Design and Develop Prototype Spacecraft Time and Frequency Reference System.	Varian Associates	Do.
Particle Parameter Analyzing System	Hughes Aircraft Co., Inc.	Do.
Design, Investigation and Development of Improvements for St-12/M Stabilized Platform Slip Ring Capsules.	Litton Precision Products	Do.
Fabricate and Test Catalytic Combustion Air Purification.	Prototech Co.	Do.
Feasibility Study of Improving Mission Capabilities of Unmanned Spacecraft.	Hughes Aircraft Co., Inc.	Do.

Patent Waivers Granted and Denied by NASA Upon Recommendation of the Agency's Inventions and Contributions Board—Continued

Contract Work[1]	Petitioner	Action on Petition
Laser Analysis for Inertial Component of the Gyroscope.	Honeywell, Inc.	Do.
Study of Advanced Techniques for Achieving Practical Spaceborne Memories.	do	Do.
Study of Foil Bearing Rotor Support System	Ampex Corp.	Do.
R&D of a Thin Film Space Charge Limited Triode.	Hughes Aircraft Co., Inc.	Do.
Electronically Steerable High Gain Antenna for Systems Applicable to Communication Spacecraft.	do	Denied
Theoretical and Experimental Investigation of Feasible and Economical Methods of Providing an Apparatus Capable of Converting Either AC or DC Input into a High Quality AC output.	Westinghouse Electric Corp., Aerospace Electrical Division.	Granted
Development of a Read Only Memory System	Radio Corp. of America	Granted
R&D of Reliable Random Access Spacecraft Memories.	General Precision	Do.
Advanced Bladder Technology	Swift & Co.	Do.
Thrustor Operation Detection Switch for the Lunar Module Reaction Control System.	Electro-Optical Systems, Inc.	Do.
Cold Cathode Gauge	National Research Corp.	Do.
X-Ray Analysis of Lunar Samples	Philips Laboratories, Div. of North American Philips Co.	Do.
Testing of Wheel Drive Mechanism for LEM	United Shoe Machinery Corp.	Do.
Infrared Interferometer Drive System	Block Engineering, Inc.	Do.
Fabrication of Apparatus for Determining Density of Liquid Hydrogen by Measuring Radiation Attenuation.	Industrial Nucleonics Corp.	Do.
Electric Superconducting Power Supply	General Electric Company	Do.
R&D Data Compression System	Texas Instruments, Inc.	Do.
Data Automation Subsystem and Bench Checkout Equipment.	Litton Systems, Inc.	Do.
Silicon Photodiode Sensor Array Design And Development.	Honeywell, Inc.	Do.
Semiconductor Detector Material Research Program.	Isotopes, Inc.	Action Deferred.
Stop-start Study of Solid Propellants	United Technology Center/ United Aircraft Corp.	Do.
Flight Telemetry Systems	Texas Instrument, Inc.	Do.
Mariner-Mars Flight Data Storage Subsystem	do	Do.
Study of Optical Processing Techniques to Aerospace Flight Problems.	University of Michigan	Do.
Study of Radiation-Type Instrumentation to Measure Propellant Mass Aboard an Orbiting Space Vehicle.	Industrial Nucleonics Corp.	Do.
Fabrication of Instrument or Apparatus Capable of Determining the Density of Liquid Hydrogen by Measuring Radiation Attenuation.	do	Do.
To provide an Experimental Package for the NASA ATS Program.	Hughes Aircraft Co.	Do.
Basic Research Program for Ferromagnetic Fluids and Their Properties.	Avco Corp.	Do.
Voice Broadcast Mission Study	Radio Corp. of America	Do.
Proposal to Furnish Infrared Imaging System	Texas Instruments, Inc.	Do.
State-of-the-art Study of Infrared Photographic Materials and techniques.	Technical Operations, Inc.	Do.

[1] Blanket waiver of all inventions made during contract performance.

Appendix J

Scientific and Technical Contributions Recognized by the Agency's Inventions and Contributions Board

(July 1—December 31, 1966)

Awards Granted Under Provisions of Section 306 of the Space Act of 1958

Contribution	Inventor (s)	Employer
Underwater Location System	John C. McFall, Jr. and Ray W. Lovelady.	Langley Research Center.
Solar Cell Submodule	Robert K. Yasui	Jet Propulsion Laboratory.

Appendix K

Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954

(July 1—December 31, 1966)

Contribution	Inventor(s)	Employer
Coordinate System Converter	Weneth D. Painter	Flight Research Center.
Recovery of Radiation Damaged Solar Cells through Thermal Annealing.	Pao-Hsien Fang and George Meszaros.	Goddard Space Flight Center.
Circuit Array Providing Minimal Induced Magnetic Fields.	Luther W. Slifer, Jr.	Do.
Method and Apparatus for Battery Charge Control.	Thomas J. Hennigan	Do.
	Nelson H. Potter	Do.
	Kenneth O. Sizemore	Do.
Precision Thrust Gage (Gauge)	Daniel J. Grant	Do.
Non-magnetic Explosive Actuated Indexing Device.	John P. Bauernschub, Jr.	Do.
Instrumentation Amplifier	Leonard L. Kleinberg	Do.
Satellite Tie-Down System	Elmer W. Travis	Do.
	Jesse M. Madey	Do.
Pulse Type Magnetic Core Memory Element Circuit.	Joseph C. Thornwall	Do.
Bidirectional Step Torque	Leo J. Veillette	Do.
Filter with Zero Backlash Characteristics	Seth R. Williams	Do.
Passive Synchronized Spike Generator with High Input Impedance and Low Output Impedance.	Ciro A. Cancro	Do.
	Paul J. Janniche, Jr.	Do.
Reaction Wheel Scanner	Gerald I. Goldberg	Do.
Method of Improving Performance Characteristics of Sealed Electrochemical Cells.	Thomas J. Hennigan	Do.
Doppler Frequency Spread Correction Device.	David W. Lipke	Do.
Selective Plating of Etched Circuits without Removing Previous Plating.	Charles E. Whitfield	Do.
Solid State, Low Power Drain Pulse Width Discriminator.	Ciro A. Cancro	Do.
Low Power Drain Semi-Conductor Circuit	Ciro A. Cancro	Do.
Complementary Reginerative Switch	Leonard Kleinberg	Do.
Apparatus for Controlling the Velocity of an Electromechanical Drive for Interferometers and the like.	Grady B. Nichols	Do.
Sealing Device for an Electrochemical Cell.	Thomas J. Hennigan	Do.
Wide Range Data Compression System	Ciro A. Cancro	Do.
Solid State Pulse Generator with Constant Output Width, for Variable Input Width, in Nanosecond Range.	Norman M. Garrahan	Do.
Ring Counter	Frederick J. Kopetski	Do.
Digital Cardiontachometer System	Virden M. Mitchell	J. F. Kennedy Space Center.
Excessive Temperature Warning System	Ian O. MacConochie	Langley Research Center.
Spacecraft Airlock	Joseph H. Judd	Do.
Semi-Linear Ball Bearing	William W. Anderson, Jr.	Do.
Circuit Module Extractor	Thomas K. Lusby, Jr.	Do.

Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954—Continued

Contribution	Inventor(s)	Employer
Electromagnetic Mirror Drive System	Norman M. Hatcher	Do.
	Nelson J. Groom	Do.
	Arthur L. Newcomb, Jr.	Do.
Leading Edge Curvature Based on Corrective Heating.	Dewey E. Wornom	Do.
Travelling Sealer for Contoured Table	Austin D. McHatton	Do.
	Bert C. Deis	Do.
Evaporant Holder and Method of making same.	Cary R. Spitzer	Do.
Spectrograph Alignment System	Reginald J. Exton	Do.
Method of Measuring the Characteristics of a Gas.	Stuart L. Seaton	Do.
Laser Calibrator	Stuart L. Seaton	Do.
Quick Release Separation Driver	William L. Newcomb	Do.
Event Recorder	James M. Russell, III	Do.
	William E. Fox	Do.
Micrometeoroid Penetration	William H. Kinard	Do.
Measuring Device	James H. Siviter, Jr.	Do.
	Charles C. Laney, Jr.	Do.
Color Filter Optical Aid	Kenneth R. Garren	Do.
	Arthur W. Vogeley	Do.
Spacecraft Separation System for Spinning Vehicles and/or Payloads.	Seymor Salmirs	Do.
	Otis J. Parker	Do.
Ablation Sensor	Archibald R. Sinclair	Do.
	James M. Russell, III	Do.
Supersonic Aircraft	Augustine W. Robins	Do.
	Roy V. Harris	Do.
	Harry W. Carlson	Do.
	Francis E. McLean	Do.
	Wilbur D. Middleton	Do.
Ablation Sensor	Peter J. Libel	Do.
Spherical Solid-Propellant Rocket Motor	Robert L. Swain	Do.
	Carl M. Styles	Do.
	Joseph G. Thibodaux, Jr. (MSC).	Do.
An Electrical Contact for a Semiconductor Surface.	Joseph Mandelhorn	Lewis Research Center.
	Jacob Broder	
Thermal Radiation Shielding	Ben T. Ebihara	Do.
Control Apparatus for Spectral Energy Source.	William A. Gordon	Do.
Alloy for Bearings	Donald H. Buckley	Do.
	Robert L. Johnson	Do.
Cobalt Alloy for Bearings	Donald H. Buckley	Do.
	Robert L. Johnson	Do.
A Cryogenic Insulation System	Porter J. Perkins	Do.
Fiber Reinforced Metallic Composites and Methods for Producing the Same.	John W. Weeton	Do.
	Max Quatinetz	Do.
	Robert W. Jeck	Do.
Titanium Base Alloy	Robert J. Johnson	Do.
	Donald H. Buckley	Do.
Method and Apparatus for Injecting Rocket Propellants.	Rudolf P. Beheim	Do.
High Powered Laser Apparatus and System.	John C. Evans, Jr.	Do.
	Henry W. Brandhorst, Jr.	Do.
Electro-Thermal Rocket	John R. Jack	Do.
	Wolfgang E. Moeckel	Do.
High Voltage Divider System	Glen E. Mealy	Do.
Refractory Metal Base Alloy Composites and Method for Producing the Same.	Max Quatinetz	Do.
	John W. Weeton	Do.
	Thomas P. Herbell	Do.
Helmet Assembly	Robert L. Jones	Manned Spacecraft Center.
	James H. O'Kane	

Awards Granted NASA Employees Under Provisions of the Incentive Awards Act of 1954—Continued

Contribution	Inventor(s)	Employer
Signal Ratio System	Richard F. Broderick	Do.
A Transpirationally Cooled Heat Ablation System.	Dr. William R. Downs	Do.
Improved Rescue Litter Floatation Assembly.	Richard A. Pollard	Do.
	Glenn A. Shewmake	Do.
Subgravity Simulator	Harold I. Johnson	Do.
	Arthur G. Trader	Do.
Shock Absorber	William K. Creasy	Do.
	James C. Jones	Do.
Cable Cutter	Thomas M. Grubbs	Do.
	Joseph A. Chandler	Do.
Cryogenic Thermal Insulation	Robert L. Middleton	Marshall Space Flight Center.
	John T. Schell	
	James M. Stuckey	Do.
Zero Gravity Apparatus	James F. Chumley	Do.
	Guy D. Perry	Do.
Elastomeric Silazane Polymers and Process for Preparing the Same.	James D. Byrd	Do.
Minaturized Solid State Television Camera System.	Carl T. Huggins	Do.
Linear Differential Pressure Sensor	James F. Milliken	Do.
Portable Milling Tool	Raymond A. Spier	Do.
Continuous Detonation Reaction Engine	Oswald H. Lange	Do.
	Richard J. Stein	Do.
	Harold E. Tubbs	Do.
Method of Detecting Flaws in Composite Structures.	Paul H. Schuerer	Do.
Detonation Reaction Engine	Oswald H. Lange	Do.
	Richard J. Stein	Do.
	Harold E. Tubbs	Do.
Automatic Welding Speed Comptroller	William A. Wall, Jr.	Do.
RC Rate Generator System for Slow Speed Instrumentation.	William M. McCampbell	Do.
	Clayton Loyd	Do.
Low Temperature Flexure Fatigue Cryostat.	Orvil Y. Reece	Do.
Method of Producing Alternating Ether-Siloxane Copolymers.	James E. Curry	Do.
Continuous Turning Slip Ring Assembly	Estel G. Lowe	Do.
Semiconducting Infrared Transmitting Glass Compositions.	Donald R. Ulrich	Do.
Optical Spin Compensator	Joseph R. Burke	Headquarters

Appendix L

EDUCATIONAL PUBLICATIONS AND MOTION PICTURES

(December 31, 1966)

NASA released the following 11 new educational publications during the last six months of 1966. These are available to the public without charge from the Media Development Division, Code FAD–1, National Aeronautics and Space Administration, Washington, D.C. 20546, or from any of NASA's Centers. Other publications are listed in a folder supplied from the same addresses.

NASA Facts

Descriptions of NASA's programs, with photographs and diagrams of spacecraft and launch vehicles.

Living in Space.—Describes life support systems devised to enable men to remain in space for prolonged periods. 12 pp.

The LASER.—Discusses the LASER beam and its role in space explorations, as well as its other applications in such fields as medicine, metallurgy, and communications. 8 pp.

Gemini Pictorial.—Features color photographs of the earth taken by the astronauts from their orbiting Gemini spacecraft. (21- by 46-inch sheet of 20 photographs and text.)

Booklets

Propulsion for Deep Space.—Descriptions of rocket systems being developed for space flights to distant points in the solar system. 29 pp.

Project Gemini.—The story of Project Gemini told in pictures. 52 pp.

The Planetarium.—A report by the University of Bridgeport, Connecticut on the projects for elementary school children in the University's planetarium. 60 pp.

Speaking of Space and Aeronautics.—Abstracts from addresses of NASA officials and others on the Nation's aeronautics and space programs for educators and the general public. The latest published were: "International Significance of the Space Program," by Dr. Robert C. Seamans, Jr., NASA Deputy Administrator (11 pp.); "The Meaning of the Space Age," by Dr. Edward C. Welsh, Executive Secretary, National Aeronautics and Space Council (10 pp.); "By-products of Space Research and Development," by Dr. Raymond L. Bisplinghoff, President, American Institute of Aeronautics and Astronautics (30 pp.); remarks made by President Johnson on September 27 during a trip to Cape Kennedy with Chancellor Erhard of the Federal Republic of Germany (6 pp.); and "Space Progress," by Dr. Lloyd V. Berkner, Chairman, Board of Trustees, Graduate Research Center of the Southwest (10 pp.)

Motion Pictures

NASA released these new films during the last six months of this year. A complete listing of available films may be obtained from the Media Development Division, Code FAD–2, National Aeronautics and Space Administration, Washington, D.C. 20546, or from any NASA Center. They may be

borrowed from the same sources without charge other than return mailing and insurance costs.

The Log of Mariner IV.—27 min., sound, color. Produced for NASA by the Jet Propulsion Laboratory. A summary of the spacecraft's flight to the vicinity of Mars.

Research Project X-15.—27½ min., sound, color (also available in 35mm, sound, color.) History of the NASA-Air Force-Navy X-15 program from the early hypersonic flight studies of the National Advisory Committee for Aeronautics through the flights of the rocket-powered research airplanes.

Returns from Space.—27 min., sound, color. Produced by the Manned Spacecraft Center. Depicts some of the effects that the aerospace industry is having on the daily lives of Americans.

Gemini Quick Look Films.—sound, color. Produced by the Manned Spacecraft Center. Flight reports on Gemini missions: IX-A (13 min.), X (9 min.), XI (16 min.), and XII (25½ min.)

The following were originally produced on videotape as the "Science Reporter" television series. Each film contains the series and the individual program title, and may be ordered as an individual film or by the series.

The First Soft Step.—28:38 min., sound, black and white. A detailed look at the overall mission and accomplishments of the Surveyor program to soft land a picture-taking spacecraft on the lunar surface. Seen are the Surveyor spacecraft, top scientists involved in its flight, and some of the photographs transmitted by it.

Landing on the Moon.—28:17 min., sound, black and white. The viewer takes a simulated ride aboard the Lunar Module in which astronauts will explore the moon's surface.

Food for Space Travelers.—28:31 min., sound, black and white. "Science Reporter" John Fitch visits a space foods kitchen and samples some of the nutritious, tasteful foods being developed for astronauts to eat during long space trips.

Power for the Moonship.—28:23 min., sound, black and white. Working models of fuel cells for the Apollo spacecraft are shown, and the possible uses of earth-based fuel cells explored.

Suited for Space.—28:30 min., sound, black and white. Space suits from the Project Mercury missions through Project Apollo to future models. A close-up of the portable life support system an astronaut may wear on the surface of the moon is also shown.

Computer for Apollo.—29:03 min., sound, black and white. Guidance and navigation on man's first trip to the moon will depend to a considerable extent on the Apollo guidance computer. This program shows how the computer works and how it is assembled.

Room at the Top.—28:13 min., sound, black and white. A detailed examination of the Command Module atop the Saturn-Apollo rocket—crew quarters, flight center, and command post for the trip to the moon.

Space Medicine.—28:31 min., sound, black and white. Dr. Charles Berry, the astronauts' medical officer, reviews the progress made in solving the medical problems of manned space flight.

Returning from the Moon.—28:21 min., sound, black and white. The problems of guidance and heating involved in the reentry of the Apollo Command Module into the earth's atmosphere. The manufacture of the ablative heat shield is also shown.

Ticket Through the Sound Barrier.—28:07 min., sound, black and white. An inspection trip of several proposed models of the supersonic transport (SST) and a "ride" in a simulated SST.

Wallops Island Launch Facility.—28:42 min., sound, black and white. "Science Reporter" Fitch visits NASA's launching site for sounding rockets for scientific experiments on the Virginia coast—a little-known but vital part of the space program.

Window on the Cosmos.—28:55 min., sound, black and white. The development, manufacture, and mission of the Orbiting Astronomical Observatory, and a closepup of the satellite just before its flight.

The Search for Extraterrestrial Life.—28:33 min., sound, black and white. Dr. Richard Young, Ames Research Center, comments on the search for life forms on other planets and describes the instruments that will be used in this research.

Appendix M

TECHNICAL PUBLICATIONS

(July 1–December 31, 1966)

The following special publications, issued during the report period by NASA's Scientific and Technical Information Division, are sold by the Superintendent of Documents, U.S. Government Printing Office (GPO), Washington, D.C. 20402, or by the Clearinghouse for Federal Scientific and Technical Information (CFSTI), Springfield, Va. 22151, at the prices listed.

Assessing Technology Transfer (NASA SP-5067).—This publication is an abridgement of a report prepared for the National Commission on Technology, Automation, and Economic Progress, which was established in August 1964. The report addresses itself primarily to one of the four official functions given to the Commission: "Assess the most effective means for channeling new technologies into promising directions, including civilian industries where accelerated technological advancements will yield general benefits, and assess the proper relationship between governmental and private investment in the application of new technologies to large-scale human and community needs." It does not recommend any single "most effective means," but considers such questions as the value of technology transfer as a national goal, the sufficiency of sources for such transfer, incentives and barriers, transfer mechanisms or channels used to date, and elements essential to effective transfer. The authors conducted depth interviews with persons in Government agencies that have technology-transfer and information dissemination programs. A comprehensive literature search was also made. 121 pp. GPO $0.50

Significant Achievements in Space Astronomy, 1958–1964 (NASA SP-91).—A report on the results brought about by the discovery and development of tools and techniques of space astronomy. The discussion deals with x-ray, gamma-ray, ultraviolet, and infrared astronomy, and low-frequency radio astronomy. A summary and conclusions are given. 73 pp. GPO $0.45

Significant Achievements in Satellite Geodesy, 1958–1964 (NASA-94).—A summary of the results of observations and analyses of Earth phenomena based on data from satellites and space probes, beginning with Vanguard I. Six sections: Early Results in Satellite Geodesy, Derivation of the Earth's Gravity Fields from Optical Photographs of Satellites, Derivation of the Earth's Gravity Field by Nonoptical Tracing. Astronomical Constants, Determination of Relative Locations of Various Areas of the Earth, and Summary and Conclusions. 174 pp. GPO $0.70

Proceedings of the Fifth National Conference on the Peaceful Uses of Space (NASA SP-82).—Papers presented at the fifth national conference held May 25–28, 1965, in St. Louis, Mo. Ten sessions: Space Exploration Accomplishments; The Space Challenge; Space Exploration Goals and Future Programs; Space Research Influences on Industry and the Economy; Space Communication; Space Research Impact on Science and Education;

Political Implications of Space Exploration; Impact on Communications; The Challenge of Space; Space Exploration Opportunities and Implications. 200 pp. GPO $1.50

Astronautics and Aeronautics, 1965. Chronology on Science, Technology, and Policy (NASA SP-4006).—A chronolgy of pertinent information on aeronautical and space affairs compiled from the open literature, documenting the events and actions of 1965. Sources include newspapers, speeches, agency releases, and magazine articles and editorials which discuss the activities of space research, space flight events, and the impact of the space age on the American scene. The book contains an extensive index as a reference for space technologists, scholars, students, writers, and historians. 681 pp. GPO $2.25

Development of a Small Animal Payload and Integration with a Sounding Rocket (NASA SP-109).—A report on the results of Phase I of the Bio-Space Technology Program, describing the design, development, and integration with a modified Arcas launch vehicle of a small-animal payload. Included are discussions of trajectory and performance, vehicle aerodynamic analysis, payload and recovery systems design, biological bench tests, payload flight-qualification testing, and flight tests and results. 98 pp. GPO $0.60

Medical Aspects of an Orbiting Research Laboratory (NASA SP-86).—A report by the Space Medicine Advisory Group (SPAMAG), a group of consultants representing varied disciplines in the life sciences who in a series of meetings were briefed on the current status of the space program and considered various aspects of a proposed biomedical program of an orbiting research laboratory. Recommendations fall in three broad categories: (1) life support; (2) experiments to test the response in the space environment; and (3) research laboratory design and operation. The life support recommendations cover hazards, atmosphere, living conditions, metabolic factors, group integrity, and medical considerations. Proposed in-flight medical experiments include both physiological and psychological tests. The third category of recommendations relate to spacecraft requirements, personnel, and laboratory facilities. 144 pp. GPO $1.00.

Orbiting Solar Observatory Satellite OSO I, The Project Summary (NASA SP-57).—Describes the work performed in connection with the Orbiting Solar Observatory launched March 7, 1962. The nine chapters give details on the dynamics of the spacecraft, structural design and fabrication, control systems, data acquisition and command systems, power supply, thermal control, testing, and experiments carried out with the OSO I. 306 pp. GPO $2.00.

Gemini Midprogram Conference (NASA SP-121).—This report contains 46 papers presented at the Gemini Midprogram Conference held at the Manned Spacecraft Center, Houston, Texas, February 23–25, 1966. The first group of 30 papers describes the spacecraft and launch vehicle, flight operations, and mission results, and includes accounts of the Gemini VI–A and VII rendezvous and the astronauts' reactions to the flight; the second group reports on in-flight experiments. 444 pp. GPO $2.75.

Summary Report on the NASA-Western University Conference (NASA SP-122).—A summary of NASA's first regional University Conference, held November 8–9, 1965, at the Jet Propulsion Laboratories in Pasadena, California, with university participants drawn from the 13 Western States, including Alaska and Hawaii. At this meeting, NASA personnel

discussed the agency's accomplishments, ongoing programs, and plans for the promotion of mutually beneficial relationships between the nation's space program and the academic community. 58 pp. CFSTI $3.00.

Proceedings of a Symposium on Passive Gravity-Gradient Stabilization (NASA SP–107).—Proceedings of a symposium held at Ames Research Center, May 10–11, 1965, to document the current state of the art in hardware development for gravity-gradient control systems. Only within the last three years has hardware been developed to the stage of providing solutions to the principal practical problems. As a result, NASA is now on the threshold of developing earth-stabilization systems that promise to be simpler, lighter, cheaper, and more reliable than any previously devised. 269 pp. GPO $1.75.

Space Power Systems Advanced Technology Conference (NASA SP–131).—Proceedings of a conference held at Lewis Research Center, Cleveland, Ohio, August 23–24, 1966, to review progress in space power systems technology. The information presented includes contributions by NASA contractors and by the Department of Defense and the Atomic Energy Commission and their contractors. 285 pp. CFSTI $3.00.

Proceedings of a Conference on Theoretical Biology (NASA SP–104).—A series of discussions on de novo cell synthesis and various aspects of theoretical biology held at Princeton, N.J., November 22–24, 1963, under the sponsorship of NASA and the American Institute of Biological Sciences. 188 pp. GPO $1.00.

Vacuum Technology and Space Simulation (NASA SP–105).—A single source handbook which consolidates the numerous interacting vacuum techniques required for space simulation and which is specifically designed for the engineer who needs to purchase, operate, maintain, or otherwise use vacuum space simulation equipment and who must have a thorough understanding of the principles of vacuum technology. 306 pp. GPO $1.00.

Solid Lubricants (NASA SP–5059).—A survey on the state of development of solid lubricants for supersonic aircraft, spacecraft, and industrial application for lubrication of delicate parts at extreme temperature and pressures. The report discusses types and specifications of existing solid lubricants, commercial applicability, cost factors, theory, and new developments in the field. Methods of evaluating solid film lubricants and the test apparatus are discussed. The report was prepared under contract for NASA by Midwest Research Institute from data supplied by the aerospace industry and NASA research organizations. 115 pp. GPO $0.50.

Vibrating Diaphragm Pressure Transducer (NASA SP–5020).—This report, prepared under contract for NASA by Southwest Research Institute, describes the vibrating diaphragm pressure transducer developed at Ames Research Center for use in high-velocity wind tunnels. The instrument is used for sensing absolute gas pressures over the range of approximately 10^{-5} to 10^{3} mm Hg. When used with the appropriate electronic circuitry, a continuous pressure indication is possible with an accuracy of 1 percent over most of the range. This improved model is small, relatively rugged, and reliable. It has a fast response; does not require a vacuum reference; and lends itself readily to automatic operation. With little or no modification the transducer can be used as a differential capacitor pressure transducer, an electrometer input device of very high sensitivity, a magnetic damping measuring device, and an accurate multiplier for use with electronic analog computers. 27 pp. GPO $0.30.

NASA Contributions to Cardiovascular Monitoring (NASA SP–5041).—A survey of recent developments in cardiovascular monitoring, with emphasis on application to civilian medicine of aerospace advances in this field. A variety of monitoring systems and their potential market are discussed. 43 pp. GPO $0.25.

Conference on Selected Technology for the Petroleum Industry (NASA SP–5053).—A conference held at Lewis Research Center, Cleveland, Ohio, December 8–9, 1965, for the purpose of acquainting representatives of the petroleum industry with new technology resulting from the nation's space effort. Choice of the topics discussed was guided by a series of meetings between Lewis staff members and petroleum industry specialists intended to identify aerospace subjects of interest and potential value to the industry. 169 pp. GPO $1.25.

Nonglassy Inorganic Fibers and Composites (NASA SP–5055).—This report presents information about non-metallic, inorganic whiskers and fibers, and composites based on them that may be useful to industry. Emphasis is given to boron carbide whiskers, boron filaments, refractory ceramic fibers, and metal-fiber-reinforced metallic composites. Growth methods and properties are discussed and potential applications suggested. 44 pp. GPO $0.35.

Some New Metal and Metal-Ceramic Composites (NASA SP–5060).—This report is designed to show industrial management the current state of development of some composite materials, including dispersion-strengthened composites, fiber composites, and reinforced ceramics. The text presents only limited technical information but discusses basic concepts, problem areas, practical considerations, economic factors, and commercial application of these materials. 26 pp. GPO $0.25.

Planetary Atmospheres, A Continuing Bibliography (NASA SP–7017).—A selection of annotated references to unclassified reports and journal articles introduced into the NASA information system during the period February 1965—May 1966. A large number of these references were produced as a result of the Mariner II and Mariner IV probes of the atmospheres of Venus and Mars. A limited number of references to the atmospheres of Jupiter, Mercury, and Saturn are also included. 440 pp. CFSTI $3.00.

Previously issued under the same title: NASA SP–7017, containing references acquired from January 1962 to February 1965 (142 pp. CFSTI $3.00).

Lasers and Masers, A Continuing Bibliography (NASA SP–7009(01)).—A bibliography of annotated references on the characteristics and applications of lasers and masers that were introduced into the NASA information system between February 1965 and April 1966. 430 pp. CFSTI $3.00.

Previously issued under the same title: NASA SP–7009, containing references acquired between January 1962 and February 1965 (280 pp. CFSTI $3.00).

Particles and Fields Research, A Bibliography with Author Index (NASA SP–7026).—An extensive list of references to journal articles, books, conference proceedings, and English translations of foreign journals published between January 1958 and May 1966. Particularly comprehensive with regard to rocket and satellite research on energetic particles and on magnetic and electric fields. 164 pp. CFSTI $3.00.

Lubrication, Corrosion and Wear, A Continuing Bibliography (NASA SP-7020(01)).—Annotated bibliography of all references on this general subject that were stored in the NASA information system during the period April 1965—August 1966. 296 pp. CFSTI $3.00.

Previously issued under the same title: SP-7020, containing references acquired from January 1962 through March 1965 (162 pp. CFSTI $3.00).

Space Measurement Survey: Instruments and Spacecraft, October 1959—March 1965 (NASA SP-3028).—The first section of this volume contains fact sheets on most of the satellites and probes launched, from Sputnik 1 through Gemini III. Information includes orbital parameters, instruments carried, and experimental objectives of each orbital or deep space probe. The second section presents a discussion of each flight organized by experiment or instrumentation, including ionizing radiation, photon measurements, aeronomy measurements, magnetic fields, and micrometeoroid detectors. 1008 pp. CFSTI $3.00.

Thermodynamic, Transport, and Flow Properties for the Products of Methane Burned in Oxygen-Enriched Air (NASA SP-3035).—This report presents results of calculations to determine the composition and the thermodynamic, transport, and flow properties of gas mixtures. Properties are computed for methane burned in air enriched with oxygen so as to maintain approximately 20 percent oxygen in the combustion products. 89 pp. CFSTI $3.00.

Dynamic Stability of Rotor-Bearing Systems (NASA SP-113).—The report of an investigation of the conditions in a rotor system which can lead to a type of a self-excited, unstable motion variously known as shaft whirling, oil film whirl, resonance whip, or half-frequency whirl, but referred to here as nonsynchronous precession. The study was conducted under contract for Lewis Research Center. 228 pp. GPO $1.00.

Electron Densities and Scale Heights in the Topside Ionosphere: Alouette I *Observations over the American Continents, vols. 1 and 2* (NASA SP-3027 and NASA SP-3032).—The first two volumes in a series of four, presenting data on electron density and plasma scale height in the topside ionosphere obtained by the Alouette I satellite. The ionograms selected for analysis were chosen for nearly complete coverage over the American continents during winter, summer, and equinox months at sunspot minimum epoch of the solar cycle. 504 pp. CFSTI $3.00; 607 pp. CFSTI $3.00.

Forecasts and Appraisals for Management Evaluation, vols. 1 and 2 (NASA SP-6009 and NASA SP-6009 (01)).—Intended primarily for those responsible for the administration, design, development, manufacture, and test of the Apollo System, this text emphasizes the use of forecasting devices as applied to space vehicle weight and performance. Mathematical models, performance relationships, and user's guide are presented in appendixes contained in the second volume. Vol. 1 220 pp. CFSTI $3.00; Vol. 2 370 pp. CFSTI $3.00.

Structural Systems and Program Decisions, vols. 1 and 2 (NASA SP-6008 and NASA SP-6008(01)).—Written for decision-makers who assimilate, validate, and interpret changes in baseline requirements on space vehicle programs, this study presents a computer program designed to provide management with a means of rapidly assessing the impact of design criteria changes on launch vehicle structural weight. The program is kept as flexible as possible, with necessary specialization of techniques or usage aimed at the Saturn V launch vehicle. Vol. 1 214 pp. CFSTI $3.00; Vol. 2 386 pp. CFSTI $3.00.

Preparing Contractor Reports for NASA: Data Presentation (NASA SP–7025).—This booklet presents detailed "how-to" information for authors of NASA contractor reports. Various types of graphs and tables are discussed, and suggestions are given for the most effective display of data. Emphasis has been placed upon latitude of presentation open to the author. No arbitrary restrictions are imposed, but concrete suggestions are given for economical effective preparation. 19 pp. GPO $0.15.

NASA Special Publications, Fall 1966.—This semi-annual listing describes some 200 NASA Special Publications issued through July 1966. Included are accounts of space exploration, conference proceedings, state-of-the art reviews in various scientific and technical fields, handbooks, bibliographies, and a series of Technology Utilization Surveys and Reports on space technology innovations that hold promise for more general industrial application. The catalog is available free on request from the NASA Scientific and Technical Information Facility, P.O. Box 33, College Park, Md. 20740.

Appendix N

Major NASA Launches

(July 1-December 31, 1966)

Name, date launched, mission	Vehicle	Site[1]	Results
Explorer XXXIII, July 1 Scientific probe to study phenomena in interplanetary space near the earth.	Improved Thrust-Augmented Delta.	ETR	This Anchored Interplanetary Monitoring Platform achieved an orbit with an apogee of 295,900 miles and a perigee of 25,300 miles. Satellite's experiments were working well.
Apollo-Saturn (AS-203), July 5 Launch vehicle development test.	Uprated Saturn I.	ETR	Orbited S-IVB stage for a U.S. weight record of 58,500 pounds. Orbital restart capability checked out successfully. In final test of S-IVB during 4th orbit, this stage fragmented after exceeding design values.
Gemini X, July 18 Orbital manned space flight.	Titan and Atlas-Agena Target Vehicle.	ETR	First dual rendezvous; longest docking (about 39 hours): 1st use of another spacecraft to provide primary and secondary propulsion for docked manned spacecraft; extravehicular activity twice. Astronauts Young and Collins landed July 21 after 70 hours, 46 minutes (43 revolutions).
Lunar Orbiter I, Aug. 10 To photograph potential landing sites for astronauts and for unmanned Surveyor spacecraft. Also, to study the moon's gravitational field.	Atlas-Agena.	ETR	First of 5 Lunar Orbiter missions successful. Photographed 9 potential sites for manned landings and 7 others of interest. Also took pictures of far side of the moon and transmitted first view of the earth from the moon.
Pioneer VII, Aug. 17 Scientific probe to investigate phenomena in interplanetary space away from the earth. (Companion to Pioneer VI launched December 16, 1965.)	Improved Thrust-Augmented Delta.	ETR	Orbited about the sun, the 140-pound satellite carries experiments to study magnetic fields, cosmic rays, and the solar wind.
Apollo-Saturn (AS-202), Aug. 25. Launch vehicle development test.	Uprated Saturn I.	ETR	Third flight test of Uprated Saturn I (Saturn IB) and second flight test of Apollo heat shield. In this suborbital flight service module motor fired four times and sent command module into reentry at 19,900 mph. Heat shield withstood reentry and command module was recovered in good condition.
Gemini XI, Sept. 12 Orbital manned space flight.	Titan and Atlas-Agena Target Vehicle.	ETR	Carried out first-orbit rendezvous and docking and set a manned space flight altitude record of 851 miles. Astronauts Conrad and Gordon landed on September 15 after 71 hours 17 minutes of flight (44 revolutions). Computer-controlled reentry.

[1] See footnote at end of table.

Major NASA Launches—Continued

(July 1-December 31, 1966)

Name, date launched, mission	Vehicle	Site[1]	Results
Surveyor II, Sept. 20 Soft-landing lunar probe.	Atlas-Centaur	ETR	Launched on good trajectory for a lunar landing, but did not make a soft landing due to a propulsion problem at the mirdcourse correction. Hit the moon southeast of the Crater Copernicus on September 22.
ESSA III, Oct. 2 Operational weather satellite launched for the Environmental Sciences Services Administration.	Thor-Delta	WTR	Third TIROS Operational Satellite and first to carry the Advanced Vidicon Camera System. Achieved nearly polar, sun-synchronous orbit to provide daily cloud cover photographs. First launch of a Thor-Delta booster from the Western Test Range.
Atlas-Centaur (AC-9), Oct. 26 Launch vehicle development test.	Atlas-Centaur	ETR	Carried out first full-thrust restart of liquid hydrogen engine in space. Injected mass model of Surveyor spacecraft into simulated lunar transfer trajectory. Last of 8 Centaur development test flights.
Lunar Orbiter II, Nov. 6 Like Lunar Orbiter I, will photograph potential landing sites for astronauts and for unmanned Surveyor spacecraft, and study the moon's gravitational field.	Atlas-Agena	ETR	Second of 5 Lunar Orbiter missions. Photographed 13 potential primary Apollo landing sites and 17 other sites of interest including oblique views of Crater Copernicus and Marius Hills. Also took pictures of the far side of the moon not covered by Lunar Orbiter I. Provided data on lunar gravitational field.
Gemini XII, Nov. 11 Final orbital manned space flight of Project Gemini.	Titan and Atlas-Agena Target Vehicle.	ETR	Astronauts Lovell and Aldrin carried out rendezvous and docking with the target vehicle. Aldrin made 2 standup EVA's and one umbilical EVA, performing work tasks in space. After flight of 94 hours, 34 minutes, 30 seconds, Gemini XII landed in Atlantic about 3 miles from the recovery ship.
ATS-I, Dec. 6 The first Applications Technology Satellite, to conduct experiments in communications, meteorology, and geophysics.	Atlas-Agena	ETR	Placed into nearly synchronous 22,300-mile orbit roughly half way between Tahiti and Hawaii. Satellite's spin scan camera able to photograph changing cloud patterns over the world for an entire day. Was the first to relay messages directly to in-flight aircraft using existing VHF equipment. Spacecraft being used for experimental testing 24 hours a day.
Biosatellite I, Dec. 14 First in a series of recoverable biological satellites to determine the effects of the space environment on various life processes.	Improved Thrust-Augmented Delta.	ETR	Spacecraft systems and biological experiments performed normally. However, satellite could not be recovered on December 17 as planned because retrorocket failed to fire. (Initial perigee, 159 miles; apogee, 178 miles.)

[1] ETR—Eastern Test Range, Cape Kennedy, Florida
WTR—Western Test Range, Point Arguello, California

Appendix O

NASA Launch Vehicles

Vehicle	Stages	Payload in pounds: 345 mile orbit	Payload in pounds: Escape	Payload in pounds: Mars/Venus	Principal use
Scout	4	240 to 300			Launching small scientific satellites and reentry probes (Explorer XXX. SERT Ion engine, San Marco I, UK–2, ESRO cooperative projects.)
Delta	3	800	150		Launching scientific, meteorological, and communications satellites TIROS IX, Orbiting Solar Observatories—OSO I and II, Ariel, Telstar I, Relay, Syncom II, Interplanetary Monitoring Platforms (Explorers XXI and XXVIII), Energetic particles satellite (Explorer XXVI).
Thrust Augmented Delta (TAD).	3	1,100	250	220	Launching scientific, meteorological, communications, and Bioscience satellites, and lunar and planetary probes (Pioneer VI, TIROS K, TIROS operational satellites OT–3 and OT–2, Syncom III, Commercial Communications Satellite Early Bird Radioastronomy Explorers, Biosatellites A—F. INTELSAT I and II communications satellites, international satellites for ionospheric studies —ISIS).
Thor-Agena	2	1,600			Launching scientific, communications, and applications satellites (Echo II, Nimbus I, Polar Orbiting Geophysical Observatory, Orbiting Geophysical Observatory II).
Thrust Augmented Thor-Agena (TAT).	2	2,200			Launching geophysics and astronomy and applications satellites (OGO C, D, and F, and Nimbus B).
Atlas-Agena	2½	5,400	950	600	Launching heavy scientific satellites, and lunar and planetary probes (Rangers VII, VIII and IX, Mariners III and IV, Orbiting Geophsical Observatory—OGO–I, Lunar Orbiters I and II Applications Technology Satellite—ATS–I.)
Atlas-Centaur	2½	8,600	2,750	1,800	Launching heavy unmanned spacecraft for various missions, including Surveyor, the Orbiting Astronomical Observatory, the Applications Technology Satellite.
Saturn IB	2	28,500			Launching Project Apollo spacecraft:
Saturn V	3	220,000	95,000	70,000	Do.

Appendix P

NASA International Activities Summary

(Cumulative through December 31, 1966)

Location [1]	Cooperative projects							Operations support (tracking and data acquisition networks)						Personnel exchanges			
	Flight projects			Ground-based projects for—													
	Satellites	Experiments on NASA satellites	Sounding rockets	Meteorological satellites	Communications satellites	Ionospheric satellites	Geodetic satellites	Scientific satellites	Manned flight	Deep space	Optical	Moonwatch	Data acquisition	Resident research associateships	International fellowships	Training at centers	Visits
Argentina			X	X		X					X	X		X	X	X	X
Ascension Island									X	X							
Australia			X	X	X	X		X	X	X	X	X		X		X	X
Austria				X		X						X		X	X		X
Belgium				X		X						X		X	X		X
Bermuda									X								X
Bolivia						X											X
Brazil			X	X	X	X					X	X	*X	X	X	X	X
Burma				X													X
Canada	X		X	X	X	X		X				X		X		X	X
Canton Islands (U.S.-U.K.)									X								
Ceylon														X			X
Chad				X													X
Chile						X		X				X		X		X	X
China, Republic of				X								X		X	X		X
Colombia				X		X								X			X
Costa Rica				X													X
Czechoslovakia				X													X
Denmark			X	X	X	X						X		X	X		X
Ecuador								X				X				X	X
El Salvador				X													X

See footnotes at end of table.

NASA International Activities Summary—Continued

Location [1]	Cooperative projects							Operations support (tracking and data acquisition networks)						Personnel exchanges			
	Flight projects			Ground-based projects for—													
	Satellites	Experiments on NASA satellites	Sounding rockets	Meteorological satellites	Communications satellites	Ionospheric satellites	Geodetic satellites	Scientific satellites	Manned flight	Deep space	Optical	Moonwatch	Data acquisition	Resident research associateships	International fellowships	Training at centers	Visits
Ethiopia											X						X
Finland						X	X										X
France	X	X	X	X	X	X	X					X		X	X	X	X
Germany, Federal Republic of	X		X	X	X	X	X					X	*X	X	X		X
Ghana						X											X
Greece			X			X						X		X			X
Hong Kong				X		X											X
Hungary				X													X
Iceland				X													X
India			X	X	X	X					X		X	X		X	X
Indonesia				X													X
Iran											X	X		X			X
Iraq				X													X
Ireland				X													X
Israel			X			X						X		X			X
Italy	X	X	X		X	X						X		X	X	X	X
Jamaica				X		X											X
Japan			X	X	X	X					X	X	*X	X	X	X	X
Kenya				X		X											X
Korea														X			X
Madagascar								X	X								X
Mauritius				X								X					
Mexico									X			X			X		X
Mozambique				X													
Netherlands		X	X	X		X	X				X	X		X	X	X	X
New Zealand			X	X		X						X		X			X
Nigeria						X			*X			X					X

Norway			X	X	X	X								X	X	X	X
Pakistan			X			X						X		X	X	X	X
Peru						X		X			X	X			X	X	X
Philippines												X					X
Poland				X								X					X
Portugal				X								X					X
Rhodesia				X													X
Senegal				X													X
Singapore				X		X											X
South Africa				X				X		X	X	X		X		X	X
Spain			X		X	X			X	X	X			X	X	X	X
Sudan				X		X											X
Sweden			X		X	X	X							X	X	X	X
Switzerland				X		X	X					X		X	X		X
Tanzania									*X								X
Thailand				X		X											X
Turkey														X			X
United Arab Republic				X										X			X
United Kingdom	X	X	X	X	X	X	X	X				X		X	X	X	X
Uruguay												X		X			X
U.S.S.R.	(2)						X										X
Venezuela														X			X
Zambia												X					X
ESRO [2]	X															X	X
Total	6	4	19	42	13	35	8	8	9	4	11	32	4	33	19	19	[3] 124

[1] Includes countries, separate jurisdictions and ESRO (Belgium, Denmark, France, Germany, F.R., Italy, Netherlands, Spain, Sweden, Switzerland, United Kingdom).

[2] Agreements provide for: (1) Cooperative communications satellite experiments via Echo II, (2) coordinated launchings of national meteorological satellites and data exchange, (3) launchings of national satellites equipped for magnetic measurements and exchange of processed data, and (4) joint review of space biology and medicine.

[3] The following, included in the total, participated in the visitor program only: Afghanistan; Algeria; Barbados B.W.I.; Bulgaria; Burundi; Camerron; Central African Rep.; Congo (Leopoldville); Cyprus; Dahomey; Dominican Rep.; Dubai; ELDO; Gabon; Gambia; Guatemala; Guinea; Guyana; Haiti; Honduras; Ivory Coast; Jordan; Kuwait; Laos; Lebanon; Liberia; Libya; Lithuania; Luxembourg; Malawi; Malaysia; Mali; Malta; Mauritania; Morocco; Nepal; Nicaragua; Niger; Panama; Paraguay; Romania; Rwanda; Saudi Arabia; Sierra Leone; Somalia; S. Viet-Nam; Swaziland; Syria; Tobago; Trinidad; Tunisia; Uganda; Upper Volta; Yemen; and Yugoslvaia.

*Discontinued.

Appendix Q

Grants and Research Contracts Obligated*

(July—December 1966)

ALABAMA:		
NsG 381	Alabama, University of, R. HERMANN AND G. CROKER Research in the Aerospace Physical Science.	$475,000
ALASKA:		
NsG 406 S 3	Alaska, University of, W. B. MURCRAY Experimental Studies of Auroral Phenomena Including Particulate Fluxes by Means of Rocket-Borne Experiments.	30,042
ARIZONA:		
NGR 03-001-013 S 1	Arizona State University, J. A. AVERY Investigation of the Dynamic Behavior of Thin Spherical Shells.	11,518
NGR 03-001-033	Arizona State University, D. A. GYOROG Heat Transfer Between Surfaces in Contact.	16,480
NGR 03-002-044 S 1	Arizona, University of, D. KECECIOGLU Investigation of Methodology for Designing Specified Reliabilities into Mechanical Components.	17,000
NGR 03-002-068	Arizona, University of, R. W. LANSING Electrophysiological and Performance Measures of Visual Excitability Cycles in Man.	38,370
NsG 120 S 5	Arizona, University of, R. W. WYCKOFF Generation and Detection of Ultra-Long Wavelength X-rays and Quantitative Studies of Their Interaction with Matter.	49,518
NsG 458 S 3	Arizona, University of, S. A. HOENIG Theoretical and Experimental Studies of Chemisorption Phenomena and Techniques, for Detection and Analysis of Tenuous Planetary Atmospheres.	40,000
NsG 628 S 2	Arizona, University of, S. BASHKIN Studies in Optical Spectroscopy.	100,252
NsG 646 S 4	Arizona, University of, G. A. KORN Experimental and Theoretical Investigations of Advanced Hybrid (Digital-Analog) Computing Techniques and Devices.	20,667
NGR 03-041-001	Sensory Systems Laboratory, H. A. BALDWIN Interpretation of telemetered Physiological Responses.	30,280
ARKANSAS:		
NGR 04-001-014	Arkansas, University of, G. V. DALRYMPLE The Role of Nucleotide Metabolism In the Repair of Radiation Injury.	32,495
CALIFORNIA:		
NGR 05-002-034 S 1	California Institute of Technology, H. ZIRIN Research in Solar Flares and the Solar Atmosphere.	201,008
NsG 172 S 6	California Institute of Technology, W. C. KNAUSS Investigation of Failure Criteria for Viscoelastic Materials.	65,000

*The grants listed in this appendix are reported to the Congress in compliance with the requirements of the grants statute, 42 U.S.C. 1891–93 (72 Stat. 1793).
Contracts have prefix NASr or NSR; grants have prefix NsG or NGR; transfer of funds to Government agencies have prefix R. Earlier grants and contracts are listed in appendices of previous NASA Semiannual Reports to Congress.

NsG 426 S 4	California Institute of Technology, R. B. LEIGHTON Space-Related Research in Selected Fields of Physics and Astronomy, including Cosmic Rays, Interplanetary Magnetic Fields, Solar Physics, Theoretical Astrophysics, Planetary Spectroscopy and Infrared Astronomy.	429,500
NGR 05-003-090 S 1	California, University of (Berkeley), W. D. BROWN AND D. B. MENZEL. Study of Environmental Efforts Upon Cellular Autoxidation.	58,000
NGR 05-003-118 S 1	California, University of (Berkeley), R. OSTWALD Nutritional Requirements and Breeding Behavior of Perognathus.	19,988
NGR 05-003-161	California, University of (Berkeley), H. P. SMITH Laser Surface Interaction: Creation and Detection of Atomically Clean Surfaces.	157,473
NsG-354 S 4	California, University of (Berkeley), C. A. DESOER Advanced Theoretical and Experimental Studies in Automatic Control and Information Systems.	60,000
NsG-387 S 4	California, University of (Berkeley), K. A. ANDERSON The Study High Energy Radiation Associated with Solar Flares and Auroral Zone Phenomena.	36,170
NsG 397 S 3	California, University of (Berkeley), N. PACE A Study of the Physiological Mechanisms of Hibernation in Hibernators Living at High Altitudes.	75,000
NsG-479 S 3	California, University of (Berkeley), T. H. JUKES The Chemistry of Living Systems.	400,000
NsG 513 S 4	California, University of (Berkeley), N. PACE Primate Hemodynamics and Metabolism Under Conditions of Weightlessness, for the Purpose of Defining and Verifying an Experiment Suitable for Use in a Biosatellite.	250,000
NsG 704 S 2	California, University of (Berkeley), A. D. MCLAREN An Investigation of Enzyme Assay Techniques for Life Detection in Extraterrestrial Soils.	110,000
NGR 05-004-021	California, University of (Davis), E. M. BORNAUER Redistribution of Body Fluids, Tissue Components and Renal Function During Non-Active States.	55,765
NGR 05-004-026	California University of (Davis), L. D. CARLSON Peripheral Volume Measurements as Indices of Peripheral Circulatory Factors in the Cardiovascular Orthostatic Responses.	33,378
NGR 05-007-041 S 2	California, University of (Los Angeles), Z. SEKARA Feasibility Studies of Coordinated Radiation Experiments from Meteorological Satellites.	97,000
NGR 05-007-077 S 1	California, University of (Los Angeles), I. R. KAPLAN Investigation of Techniques for Analysis of Ancient Sediments and Extraterrestrial Materials.	5,000
NGR 05-007-116	California, University of (Los Angeles), A. BANOS Theoretical Study of Non-Linear Waves and Shock-Like Phenomena in Hot Plasmas.	29,899
NsG 502 S 3	California, University of (Los Angeles), J. D. FRENCH Neurophysiological and Behavioral Studies of Chimpanzees, Including Establishment of a Group of Implanted Animals Suitable for Space Flight.	105,000
NsG-721 S 1	California, University of (Los Angeles), R. E. SMITH The Role of Brown Fat in the Thermogenesis of Animals and Man.	35,000
NSR 05-007-094	California, University of (Los Angeles), G. J. P. MACDONALD. A feasibility Study of a Small Satellite of the Scout class to Investigate the Interplanetary Medium, the Magnetosphere and the Transition Planetary Medium.	55,539

NGR 05-009-025 S 1	California, University of (San Diego), P. A. LIBBY. Mass Transfer in Laminar Hypersonic Boundary Layers.	50,575
NsG 541 S 4	California, University of (San Diego), H. C. UREY. Analysis of the Organic and Inorganic Constituents of Carbonaceous and Other Selected Stony Meteorites.	60,000
NsG 722 S 2	California, University of (San Francisco), H. J. RALSTON AND V. T. INMAN. Relative Roles of Gravitational and Inertial Work in the Energy Cost and Character of Human Locomotion.	42,000
NSR 05-264-002	Earth Science Research Corporation, D. L. LAMAR. Study of Shape and Internal Structure of Moon Utilizing Lunar Orbiter Data.	26,022
NGR 05-035-003 S 1	Institute for Lipid Research, C. E. ENTENMAN. Study of Body Energy Conservation in Relation to Space Flight Environmental Effects on Organisms.	30,000
NGR 05-029-001 S 1	San Francisco, University of, A. FURST. Brain Amino Acids and Biogenic Amines Under Various Atmospheric Mixtures.	21,628
NASr 49(22) A 1	Stanford Research Institute, A. S. DENNIS. Study of the Feasibility and Applicability of Laser Measurements from a Meteorological Satellite.	2,610
NASr-49(24)	Stanford Research Institute, T. J. AHRENS AND P. S. DECARLI. An Investigation of the Shock-Induced Transformation of Plagioclases, Olivines, and Pyroxenes.	52,280
NASr-49(25)	Stanford Research Institute, A. UNG AND R. ROBBINS. Conduct a Laboratory Investigation of the Origin of the Venusian Clouds.	45,370
NGR 05-020-177	Stanford University, R. E. SMITH. Subcellular Localization of Pituitary Enzymes.	35,780
NsG 174 S 4	Stanford University, R. A. HELLIWELL. Investigation of Experimental Techniques for Measurement of Very Low Frequency Electromagnetic Phenomena in the Ionosphere.	50,000
NsG 331 S 4	Stanford University, A. SCHAWLOW. Spectroscopic Studies in Infrared and Optical Quantum Electronics.	100,000
R 05-030-004	U.S. Navy/Naval Ordinance Test Station, A. J. KRUEGER. To Provide Comparative Optical and Ozone Data for OGO IV Ultraviolet Monochromator Ozone Measurements.	78,000
R 05-051-001	U.S. Army Corps of Engineers. Radioisotopic Tracer Investigation of Littoral Transport Around Point Conception, California.	20,000
COLORADO:		
NSR 06-043-001	Colorado Engineering Experiment Station, B. T. ARNBERG. Mass Flow Measurement Research.	60,000
NASr-147 A 6	Colorado State University, W. E. MARLATT. Investigation of the Temperature and Spectral Emissivity Characteristics of Cloud Tops and of the Earth's Surface.	150,000
NGR 06-002-038	Colorado State University, W. R. MICKELSEN AND R. W. PRICE. Multidisciplinary Space-Related Research in the Physical, Engineering and Life Sciences.	200,000
NASr 185 A 4	University Corporation for Atmospheric Research, K. O. KIEPENHEUER. Development of Improved Means of Scientific Ballooning and the Conduct of Scientific Balloon Flights.	300,000

NsG 404 S 3	University Corporation for Atmospheric Research, J. A. Eddy. Investigations of Observational Means of Examining the Solar Corona Including Design Studies of a Solar Coronagraph.	78,000
R 06-012-006	U.S. Environmental Science Services Administration, J. W. Wright. Ionospheric Electron Density Studies and Computations.	50,000
R 06-012-007	U.S. Environmental Science Services Administration, E. C. Whipple. D-Region Investigation with Ionospheric Experiments on Nike-Cajun Rocket Coordinated with a GSFC Aerobee Payload Instrumented for Micrometeorite Measurements.	49,700
R-45 A 8	U.S. National Bureau of Standards, F. Schulman Investigations and Research on Cryogenic Properties and Processes.	435,000
R-65 A 1	U.S. National Bureau of Standards Planning and Designing a Topside Sounder Experiment to Observe a Planetary Ionosphere, including the Study, and Development of Models of the Ionosphere of Mars and Venus.	1,003
R 06-006-046 A 1	U.S. National Bureau of Standards Conduct a Critical Evaluation for the Thermophysical Property Data from the Scientific Literature for Materials at Temperatures from Cryogenic to Ambient.	190,000
R 06-006-056	U.S. National Bureau of Standards, R. Cohen Conduct Study of Ionospheric and Telecommunications Experiments on Manned Spacecraft.	12,000
Connecticut:		
NSR 07-002-015	Connecticut, University of, R. O. Harvey Study of the Feasibility of Establishing a Regional Dissemination Center in the New England Area.	56,354
NGR 07-009-001	Rensselaer Polytechnic Institute of Connecticut, Inc., H. J. Schwartz. Non-Magnetic Ionization Gauge with Low X-ray Limit.	20,800
NsG 138 S 5	Yale University, R. C. Barker Low-Power, Low-Speed Data Storage and Processing Techniques.	35,000
NsG 192 S 4	Yale University, S. R. Lipsky Development of Experimental Gas Chromatography-Mass Spectrographic Techniques.	74,980
NsG-724 S 1	Yale University, M. M. Chen An Experimental and Theoretical Research on Plasma Sheaths and Boundary Layers around Stagnation Point Electrodes.	35,995
Delaware:		
None		
District of Columbia:		
NASr-238 A 1	Federation of American Societies for Experimental Biology, P. L. Altman The Accumulation, Analysis, Compilation of Data, and Preparation of a Camera-Ready of a Handbook on Environmental Biology.	25,000
NsG 362 S 1	Georgetown University, F. J. Heyden Spectroscopic Study of Solar and Planetary Atmospheres.	31,789
NASr 171 A 5	George Washington University, C. W. Shilling Review and Evaluation of New Technology in the Biomedical Field.	4,997

NGR 09-010-030	George Washington University, L. H. MAYO Multidisciplinary Program of Policy Studies in Science and Technology.	750,000
NGR 09-010-030 S 1	George Washington University, L. H. MAYO Multidisciplinary Program of Policy Studies in Science, Technology and Public Administration.	25,000
NsG 603 S 3	George Washington University, N. FILIPESCU Synthesis and Spectroscopic Properties of Rare Earth Chelates in Solvents and Polymers for Optical Masers.	27,907
NGR 09-011-004 S 1	Howard University, H. BRANSON Research in the Space Sciences.	26,000
NASr 62 A 7	National Academy of Sciences, S. S. STEINBERG NASA International University Fellowship Program.	320,000
NsG-492 S 2	National Academy of Sciences, H. R. SPRAGUE Partial Support for the Committee on the Use of Aerial Photographic Survey in Agriculture. Criteria for Feasibility of Identifying Vegetation by Spectral Signatures will be examined.	12,500
NSR 09-012-901 A 5	National Academy of Science, C. J. LAPP Postdoctoral and Senior Postdoctoral Resident Research Associateships in Space Sciences and Technology.	2,202,000
NSR 09-012-906	National Academy of Sciences, G. M. CLEMENCE Astrometric Survey of the Southern Sky.	28,060
NSR 09-012-907	National Academy of Sciences, L. SLACK Preparation and Publication of a Comprehensive Summary Report of the Scientific Proceedings of the XV General Assembly of the International Scientific Radio Union, Munich, Germany, September 1966.	6,000
NSR 09-013-008	National Science Teachers Association, R. R. CARLETON The Conduct of Nine Youth Science Congresses by the National Science Teachers Association.	31,550
NsG 87 S 16	Smithsonian Institution, F. L. WHIPPLE Optical Satellite Tracking Program.	237,198
NsG-87 S 17	Smithsonian Institution, F. L. WHIPPLE Optical Satellite Tracking Program.	1,348,500
NsG-563 S 1	Smithsonian Institution, C. W. TILLINGHAST A Study of the Search, Recovery and Analysis of Space Fragments.	40,075
R 09-147-001	U.S. Army Materiel Command, S. F. HEAL LSSM Man-Vehicle Interface Demonstration.	1,640
R-104(04) A 3	U.S. Atomic Energy Commission, M. A. BENDER S-4 Human Blood Irradiation Experiment.	263,000
R 104(06) A 3	U.S. Atomic Energy Commission, J. V. SLATER Conduct a Feasibility Study for an Experiment Suitable for Use in a Biosatellite, to Determine the Effect of the Space Environment Complex on Insect Growth and Development.	42,707
R-104(07) A 4	U.S. Atomic Energy Commission, A. SPARROW The Completion of the First 3-day Bio-Satellite Flight.	6,000
R-104(11)	U.S. Atomic Energy Commission, C. A. TOBIAS Calibration Studies for Cosmic Ray Particle Measurement.	10,000
R 09-020-029	U.S. Department of Interior/Geological Survey, W. SIBERT. Studies Related to the Requirements and Performance Specifications of Panoramic Cameras.	30,000

R–141 A 4	U.S. Library of Congress, P. L. BERRY Scanning, Selecting, Abstracting and Indexing Services of Current Literature in the Fields of Aerospace Medicine, Biology, and Related Subjects.	14,000
R 09–022–052 A 1	U.S. National Bureau of Standards, A. BRENNER Investigate the Electrolysis of Solid Salts and Ceramic Materials by Connecting the Materials to the Positive Pole of a Current Source and then Subjecting the Materials to an Electron Beam in a Vacuum.	23,500
R–138 A 2	U.S. National Bureau of Standards, G. T. ARMSTRONG Thermodynamic Properties of Molecular Complexes of the C-H-O-N-S-P System.	32,000
R 09–029–046 A 1	U.S. Navy-Naval Research Laboratory, M. H. SCHRENK Partial Support of Shock and Vibration Information Center.	45,000
R 107 A 4	U.S. Navy-Naval Research Laboratory. H. FRIEDMAN Research on Solar Instrumentation for Advanced Orbiting Observatories.	500,000
FLORIDA:		
NGR 10–004–029 S 1	Florida State University, R. G. CORNELL Space-Related Biostatistical Studies, Emphasizing Microbiology and Sterilization.	46,414
NGR 10–005–062	Florida, University of, C. LOWE Primitive Earth Synthesis of Amino Acids and Polypeptides.	34,612
NGR 10–005–068	Florida, University of, R. B. PEREZ Theoretical Investigation of a Self-Sustained Nuclear Plasma Source.	24,889
NsG 689 S 4	Miami, Unviersity of, S. W. FOX Investigation in Space-Related Biology, Including Molecular Evolution and Relevant Aspects of the Extraterrestrial Environment.	199,260
NGR 10–008–009	University of South Florida, R. E. WILSON Star Tracking Guidance Techniques.	25,000
R 39 A 4	U.S. Navy—School of Aviation Medicine, D. E. BEISCHER. Conduct Research on the Effect of Very Strong Magnetic Fields and of Magnetic-Field-Free Environments on Animals and Man.	48,000
R 93 A 4	U.S. Navy—School of Aviation Medicine, S. A. GRAYBIEL. Investigate the Physiological & Psychological Effects of Gravitational & Inertial Forces on Man in a Manner which Extends Man's Basic Knowledge of the Area and Simultaneously Applies this Knowledge to Operational problems.	250,000
R 10–009–013 A 2	U.S. Navy—School of Aviation Medicine, A. GRAYBIEL Research in Subhuman Primates in Long Duration Orbital Flight with Rendevous Recovery #1, 2, 3, 4, 5 and 10.	174,497
GEORGIA:		
NGR 11–001–012 S 2	Emory University, B. W. ROBINSON Study of Control and Analysis of Primate Behavior by Brain Telestimulation and Telemetry.	100,000
NGR 11–001–016	Emory University, G. H. BOURNE Histopathological and Histochemical Study of Sub-Human Primates.	67,710
R 137 A 3	U.S. Department of Health, Education, Welfare, S. W. SIMMONS. Research on Microbiological Sterilization Problems Involving the Safety of Earth and Other Planets of this Galaxy from the Effects of Intra-Spatial Transmission of Potentially Virulent Microorganisms.	320,000

HAWAII:		
NASr-5 A 8	Hawaii, University of, H. C. McALLISTER Design, Construction and Application of an Echelle Spectrograph-Spectrometer Suitable for use in an Earth Satellite.	255,732
NsG 676 S 3	Hawaii, University of, J. L. WEINBERG Photoelectric Study of the Night-Sky Radiation from Zodiacal Light, Airglow, and Starlight.	53,967
IDAHO:		
NONE		
ILLINOIS:		
NGR 14-001-054 S 1	Chicago, University of, W. A. HILTNER Study of the Variable Polarization of the Visible Radiation from Magnetic Variable Stars.	20,963
NsG 333 S 3	Chicago, University of, T. FUJITA Meteorological Interpretation of Satellite Radiation Data.	55,000
NsG 366 S 5	Chicago, University of, E. ANDERS An Investigation of the Origin, Age, and Composition of Meteorites.	100,000
NsG 441 S 4	Chicago, University of, H. F. MORAN Investigations in Space-Related Molecular Biology Including Considerations of the Molecular Organizations in Luster Sounding Rocket Programs.	200,000
NsG 467 S 2	Chicago, University of, C. O. HINES A Theoretical Investigation of Upper Atmosphere Dynamics, Including the Effects of Tidal Oscillation, and Smaller Scale Random Motions.	55,522
NASr-22 A 7	IIT Research Institute, E. J. HAWRYLEWICZ Design and Construction of Environmental Chambers to Simulate the Martian Atmosphere.	30,675
NASr 65(02) A 3	IIT Research Institute, E. VEY Conduct Studies of Lunar Soil Mechanics, Including the Determination of Static Mechanical Properties of Simulated Lunar Soils Under Lunar-Like Environmental Conditions.	6,464
NASr-65(09) A 2	IIT Research Institute, S. A. BORTZ Study to Determine the Advantages of Graphite-Metal Alloys.	50,000
NASr-65(10) A 5	IIT Research Institute, C. A. STONE Scientific and Engineering Studies Related to Manned Space Science Problems.	62,803
NGR 14-004-006 S 1	Illinois Institute of Technology, T. P. TORDA Investigation of Liquid Propellants in High Pressure and High Temperature Environments.	44,000
NGR 14-005-050 S 1	Illinois, University of, R. E. JOHNSON AND F. SARGENT Investigation of Properties of Human Sweat and Factors affecting the Water Balance in Confined spaces.	33,908
NGR 14-005-088	Illinois, University of, G. C. McVITTIE Investigation of Relativistic Effects on Space Tracking Data.	15,910
NGR 14-005-097	Illinois, University of, C. D. HENDRICKS Ion Mass Spectra in the Ionospheric E-Region.	39,153
NsG 24 S 7	Illinois, University of, K. C. YEH Theoretical and Experimental Studies of Ionospheric Electron Control and Irregularities.	125,000
NsG 395 S 3	Illinois, University of, G. A. DESCHAMPS A Study of Selected Radiation and Propagation Problems Related to Antennas and Probes in Plasmas.	45,586

NsG 511 S 4	Illinois, University of, S. A. BOWHILL Investigation of the D and E Regions of the Ionosphere.	261,421
NSR 14-015-001	Michael Reese Hospital, S. NATELSON Analysis of Components in Biological Fluids in A Gravity Free Environment Emphasizing Procedure Suitable for use in an Orbiting Laboratory.	15,600
NGR 14-007-048	Northwestern University, K. G. HENIZE Feasibility and Design Study of Instrumentation for Measuring Sky Brightness.	68,000
INDIANA:		
NASr-162 A 3	Indiana University, A. M. WEIMER Pilot Program for Investigating Various Techniques to Enhance the Utilization of New Knowledge Related to or Stemming from Aerospace Research and Technology.	200,000
NSR 15-003-032	Indiana University Foundation, A. M. WEIMER Experimental Technology Utilization Program.	150,000
NsG-301 S 3	Purdue University, K. L. ANDREW High Precision Spectroscopy with Applications to the Study of the Atomic Spectra of the Carbon Group, to Secondary Standards in the Vacuum Ultraviolet, and to the Development of Computer Methods of Data Analysis.	49,742
IOWA: *NONE*		
KANSAS:		
NGR 17-004-012	Kansas, University of, K. H. LENZEN Response of Aerospace Vehicles to Gusts and Buffeting.	8,860
NsG 298 S 4	Kansas, University of, W. P. SMITH Interdisciplinary Studies in Space Science and Technology.	100,000
KENTUCKY:		
NGR 18-001-008 S 2	Kentucky, University of, R. E. SMITH Circadian Rhythms in Primates as Influenced by Latitude, Longitude, Gravity and Confinement.	93,966
NGR 18-002-008 S 1	Louisville, University of, E. A. ALLUISI Performance Measurements of Intellectual Functioning.	35,977
LOUISIANA:		
NGR 19-001-018	Louisiana State University, A. ZETTL Symmetry in Non-Self Adjoint Boundary Value Problems.	5,202
NGR 19-001-019	Louisiana State University, D. R. TOMPKINS A Cosmic Ray Search for Magnetic Monopoles.	17,591
NGR 19-001-024	Louisiana State University, J. M. REYNOLDS Multidisciplinary Research in Space Sciences and Engineering.	200,000
MAINE: *NONE*		
MARYLAND:		
NsG-450 S 5	Institute for Behavioral Research, Inc., C. B. FERSTER Experimental Studies of Perceptual Processes.	113,166
NGR 21-001-035	Johns Hopkins University, S. A. WEINSTEIN Behavioral Regulation of Gaseous Environments.	30,281
NGR 21-001-044	Johns Hopkins University, J. STRONG Partial Support for Observations of the Solar Corona with Balloon-Borne and Ground-Based Infrared Coronagraphs.	109,955

NsG 193 S 5	Johns Hopkins University, G. H. DIEKE Rocket and Laboratory Experiments and Analysis on the Ultraviolet Spectra of the Upper Atmosphere.	250,000
NGR 21-002-040 S 3	Maryland, University of, R. G. GRENELL Molecular Binding in the Cell Surface.	2,400
NGR 21-002-057 S 1	Maryland, University of, R. T. BETTINGER Ionospheric Investigations with In Situ Probes.	20,206
NGR 21-002-059 S 1	Maryland, University of, E. R. LIPPINCOTT Experimental Studies Concerning Equilibrium and Non-Equilibrium Systems in Pre-Biological Atmospheres.	109,998
NsG 189 S 6	Maryland, University of, J. V. BRADY Study of the Behavior of Organisms Under Conditions of Space Flight.	67,048
NsG 220 S 5	Maryland, University of, D. A. TIDMAN Theoretical Investigations of the Dynamics of Astrophysical and Geophysical Plasmas.	37,370
NsG 566 S 3	Maryland, University of, R. G. GRENELL Neurobiologic Substrates of Behavior.	100,000
NSR 21-003-002 A 2	National Biomedical Research Foundation, M. O. DAYHOFF. Study of Thermodynamic Properties of Molecular Complexes of Organic Molecular Systems.	92,679
R-35 A 6	U.S. Army Corps. Biological Laboratories, C. R. PHILLIPS. Space Vehicle Sterilization Problem.	40,000
R 21-010-017	U.S. Navy-Naval Medical Research Institute To Investigate the Physiological Effects of Stresses Undergone by Aircraft Pilots in Operational Situations and the Effects of Drugs on Visual Perception.	10,000
R-38 A 6	U.S. Navy-Naval Medical Research Institute, T. BENZINGER. Conduct Research into Microcalorimetry as a Method for Life-Detection and Assimilation of Energy and Carbon in Autotrophic Forms of Life.	75,000
R-134 A 2	U.S. Navy-Naval Medical Research Institute, D. E. GOLDMAN. Studies on the Mechanism of Axonal Conduction in Non-Myelinated Nerve.	16,400
R 120 A 4	U.S. Navy-Naval Ordnance Laboratory, E. HOOPER Research on Improved Space Magnetometers of the Fluxgate Type.	80,000
NsG 670 S 2	Woodstock College, M. J. BIELEFELD Theoretical and Experimental Studies in Planetary and Atmospheric Physics.	30,000
MASSACHUSETTS:		
NGR 22-007-059	Harvard University, K. R. PORTER The Effects of Stress on Collagen Biogenesis.	47,669
NsG 262 S 6	Harvard University, W. H. SWEET Interdisciplinary Studies of the Effects of High Energy Protons on Biologic Systems, Including Participation in the Nationwide Cooperative Study on Shielding Materials as Related to the Apollo Missions.	60,000
NsG 559 S 2	Harvard University, B. BUDIANSKY Theoretical Investigations in Structural Mechanics with Particular Emphasis on Fracture Mechanics and Thin Shell Analysis.	57,800
NsG-685 S 4	Harvard University, G. R. HUGUENIN Theoretical and Experimental Investigations in Radio Astronomy and in Long Wavelength Solar Radio Noise, Including an Astrobee-Borne Experiment for Observation of Solar Phenomena.	137,095

NSR 22-007-067	Harvard University, L. GOLDBERG Conduct an Investigation of the Center-to-Limb Variations in the Far Ultraviolet Solar Spectrum by Means of a Spectral Scanning Spectrometer Flown Aboard an Aerobee-Hi Rocket.	358,389
NSR 22-007-072	Harvard University, G. R. HUGUENIN Ground Feasibility Tests of a Unity-Gain, High Directivity Antenna.	149,582
NASr-249 A 3	Massachusetts Institute of Technology, J. V. HARRINGTON. The Study of a Radio Probe for the Extended Solar Corona.	354,051
NGR 22-009-064 S 1	Massachusetts Institute of Technology, J. V. HARRINGTON. Radar Investigations of Solar Coronal Structures and Motions at the El Campo, Texas Radar Astronomy Facility.	76,031
NGR 22-009-187	Massachusetts Institute of Technology, F. PRESS Lunar Geophysics, as related to the Apollo Applications Program.	73,782
NSR 22-009-129	Massachusetts Institute of Technology, G. W. CLARK A Program of X-Ray Astronomy from Sounding Rockets.	225,000
NsG-330 S 4	Massachusetts Institute of Technology, A. JAVAN Properties of Optical and Infrared Masers.	193,000
NsG-691 S 2	Massachusetts Institute of Technology, G. SILVERMAN The Resistivity of Microorganisms to Thermal Inactivation by Dry Heat.	33,322
NGR 22-010-018	Massachusetts, University of, R. V. MONOPOLI Pulse Frequency Modulation in Control Systems.	12,660
NGR 22-011-020	Northeastern University, J. WARGA Optimization of Trajectories by Modern Mathematical Control Theory and Functional Analysis.	29,793
NSR 22-014-001 A 1	Woods Hole Oceanographic Institution, E. T. DEGENS The Study of Biogeochemistry of Terrestrial and Extra-terrestrial Organic Matter.	31,700
MICHIGAN:		
NsG 226 S 3	Detroit, University of, A. SZUTKA Synthesis of Morphine-Like Substances from Simple Precursors.	20,000
NsG 475 S 3	Michigan State University, L. AUGENSTEIN An Investigation of the Molecular Basis and Organization of Nerve and Brain Function.	60,000
NASr-54(03) A 4	Michigan, University of, F. L. BARTMAN Development of Laboratory and Flight Experimental Techniques Directed Toward Obtaining Data to be Used in Interpreting Satellite (TIROS and NIMBUS) Radiation Measurements.	400,000
NASr-54(05) A 5	Michigan, University of, L. M. JONES Survey Measurements of Upper Air Structure.	135,000
NASr 54(05) A 6	Michigan, University of, L. M. JONES Survey Measurements of Upper Air Structure.	200,000
NASr 54(08 A 3	Michigan, University of, F. F. FISCHBACH Measurement of Atmospheric Structures by Satellite Observation of Stellar Refraction.	12,600
NGR 23-005-183	Michigan, University of, J. E. ROWE Frequency Multiplication in High-Energy Electron Beams.	75,000
NsG 344 S 3	Michigan, University of, S. K. CLARK Structural Analysis of Aircraft Tires.	30,806

NsG 525 S 3	Michigan, University of, A. NAGY Theoretical and Experimental Investigations of Plasma Waves, Space Vehicle Plasma Sheaths, and Ionospheric Electron Temperatures.	82,000
NsG 558 S 2	Michigan, University of, F. T. SUN Hydrographic Methods for the Analysis and Solution of Problems Related to Orbit and Trajectory Determination.	32,612
NsG 659 S 1	Michigan, University of, J. D. GODDARD Theoretical Study of the Rheology of Dispersed Fluid Systems (Research in Non-Newtonian Fluid Physics).	27,684
NsG 696 S 2	Michigan, University of, J. E. ROWE Non-Linear Interaction Phenomena in the Ionosphere.	40,000
NGR 23-006-036	Wayne State University, S. P. HEIMS Theoretical Research in Statistical Mechanics with Application to Rotation Phenomena.	10,000
NSR 23-006-034	Wayne State University, H. STILLWELL Study to Determine Potential Transfer of Aerospace Generated Technology for Urban Management.	29,000
MINNESOTA:		
NsG 517 S 4	Minnesota, University of, F. HALBERG Ground-based Studies on Internal and External Synchronization or Desynchronization of Mammalian Rhythms with Special Reference to the Mouse.	105,000
NGR 24-005-105	Minnesota, University of, V. R. MURTHY Elemental and Isotopic Studies of Lunar Materials.	45,000
NGR 24-005-111	Minnesota, University of, J. R. WINCKLER Electron Radar Technique as a Probe of the Trapped Radiation Belts.	128,057
MISSISSIPPI: *NONE*		
MISSOURI:		
NASr 63(10)	Midwest Research Institute, J. LOSER A Survey of Space-Oriented Value Technology as Applied to Non-Space Use.	13,278
NASr 63(11)	Midwest Research Institute, H. L. STOUT Medical Applications of NASA-Developed Science and Technology.	105,788
NGR 26-004-021 S 1	Missouri, University of, X. J. MUSACCHIA Effects of Radiation on Gastro-Intestinal Function and Cyclic Turnover of Intestinal Epithelum.	30,711
MONTANA: *NONE*		
NEBRASKA: *NONE*		
NEVADA:		
NGR 29-001-015 S 2	Nevada, University of, M. J. HIBBARD Ground Data Support for Geological Test Stand.	23,750
NEW HAMPSHIRE:		
NsG 231 S 2	Dartmouth College, C. J. LYON An Investigation of the Effects of Plant Growth Hormones on Plant Development in the Absence of Gravitational Effects.	32,058
NSR 30-001-018	Dartmouth College, T. LAASPERE For Support of an Existing Network of Whistler Ground Stations to Yield Data for Comparison with Data From OGO-II, -D, and -F.	19,500

New Jersey:		
NASr 217 A 4	Princeton University, L. Crocco Nonlinear Aspects of Combustion Instability in Liquid Propellant Rocket Motors.	70,000
NGR 31-001-044 S 2	Princeton University, R. E. Danielson Design Study of Manned Orbiting Telescope for an Extended Apollo System.	241,700
NsG-200 S 5	Princeton University, M. Summerfield Research on Ignition and Combustion Stability and Efficiency of Solid Propellants at Low Pressures.	65,000
NsG-306 S 5	Princeton University, W. Jaskowsky Studies of Pulsed Electromagnetic Gas Acceleration.	300,000
NSR 31-001-078	Princeton University, J. P. Layton Solar Electric Space Mission Analysis.	130,690
NGR 31-003-020 S 2	Stevens Institute of Technology, H. Meissner Proximity Effects Between Superconducting and Normal Metals.	15,000
NSR 31-003-016 A 3	Stevens Institute of Technology, I. R. Ehrlich Theoretical and Experimental Studies of Aircraft Tire Hydroplaning.	24,531
New Mexico:		
NGR 32-001-004 S 1	Lovelace Foundation, A. H. Schwichtenberg Investigations of Flight-Related Physical, Psychophysiological and Cardiorespiratory Stresses.	48,000
NSR 32-004-013 A 2	New Mexico, University of, H. L. Enarson A Program to Accelerate the Industrial Application of Aerospace Related Technology.	151,099
R 09-019-040 A 1	U.S. Atomic Energy Commission, H. D. Sivinski Support of the Planetary Quarantine Activities of Bioscience Programs.	250,000
New York:		
NGR 33-001-016	Adelphi University, H. Ogden Search for Faint Comets near the Sun.	11,270
NSR 33-003 009 A 2	American Institute of Aeronautics and Astronautics, J. J. Glennon. A Scientific and Technical Information Service, including Abstracting and Indexing, Covering Published Aerospace Literature.	1,582,000
NGR 33-008-037 S 2	Columbia University, J. E. Nafe Program of Research in Theoretical and Experimental Geology and Geophysics in Areas of Direct Interest to the NASA Space Science Program.	18,925
NGR 33-008-061 S 1	Columbia University, P. W. Gast Study of Alkali Metal, Alkaline Earth and Lanthanide Elements in Lunar Material.	38,294
NsG 445 S 4	Columbia University, I. Woltjer Theoretical Research in Space Sciences.	35,000
NASr-156 A 5	Cornell Aeronautical Laboratory, Inc., J. W. Ford Analytical and Experimental Research in Aerosol Physics.	76,747
NSR 33-009-029 A 1	Cornell Aeronautical Laboratory, Inc., K. D. Bird Shock Tunnel Investigations of Turbulent Flow at High Mach Numbers.	86,531
NGR 33-010-039	Cornell University, P. Van Riper Top Level Decision-Making in the National Aeronautics and Space Administration.	26,120
NGR 33-010 042	Cornell University, F. K. Moore Study of High Temperature Heat Transfer.	55,700

NEW YORK:

NSR 33-101-040	Cornell University, A. R. SEEBASS Study of Fluid Physics Areas of Contemporary and Future Interest to NASA.	20,500
NsG 155 S 4	Dudley Observatory, C. L. HEMENWAY Collection and Analysis of Micrometeorites.	120,000
NsG 699 S 2	New York University, S. BOROWITZ Selected topics in Atomic Physics.	6,000
NGR 33-018-066	Rensselaer Polytechnic Institute, J. B. HUDSON A Study of Surface Effects in Gauges for Ultra-high Vacuum Pressure Measurement.	27,000
NGR 33-018-075	Rensselaer Polytechnic Institute, E. HOLT Non-Equilibrium Properties of Magnetoplasmas.	140,000
NsG-100 S 7	Rensselaer Polytechnic Institute, S. E. WIBERLEY Interdisciplinary Materials Research.	8,200
NsG 261 S 4	Rensselaer Polytechnic Institute, P. HARTECK Chemistry of Planetary Atmospheres and Comets.	110,000
NsG 290 S 5	Rensselaer Polytechnic Institute, J. C. CORELLI Studies of Radiation Damage to Semi-Conductors and Thin Metallic Films by High Energy Electron, Proton and Neutron-Gamma Radiation.	65,000
NGR 33-019-058	Rochester, University of, G. COHEN Investigation of Computer Aided Circuit Design.	50,000
NsG 209 S 6	Rochester, University of, W. VISHNIAC Microbiological and Chemical Studies of Planetary Soils.	99,555
NGR 33-015-013 S 1	New York, State University of, R. P. TEWARSON Product Form of Inverses of Sparse Matrices.	15,736
NGR 33-022-032 S 1	Syracuse University, H. W. LIU Fatigue Crack Propagation and Strains within Plastic Zone.	24,069
NGR 33-023-024	Yeshiva University, A. G. W. CAMERON Partial Support of Symposium on Relativistic Astrophysics.	3,000
NsG 489 S 4	Yeshiva University, S. WEINSTEIN Investigation of Effects of Isolation, Sensory Deprivations of Varying Durations on Sensory, Perceptual, Physiological, Emotional and Spatial Orientation of the Individual.	20,000

NORTH CAROLINA:

NGR 34-002-036	North Carolina State University, F. O. SMETANA Experimental Investigation of the Cryoentrainment Pump.	35,292
NGR 34-002-047	North Carolina State University, F. J. TISCHER Study of Rectangular-Guide-Like Structures for Millimeter Wave Transmission.	35,000
NsG 588 S 2	North Carolina State University, R. W. LADE Theoretical and Experimental Studies of Radiation-Induced Damage to Semiconductor Surfaces and the Effects of this Damage on Semiconductor Device Performance.	59,822
NSR 34-004-035	Research Triangle Institute, R. M. BURGER and J. N. BROWN, JR. Facilitating and Intensifying the Flow of Information from Aerospace Research and Development Programs to the Medical Field.	64,926

NORTH DAKOTA:

NONE

Ohio:		
NGR 36-003-094	Case Institute of Technology, L. Leonard The Effect of Deformation on Dispersion.	24,050
NsG 728 S 2	Case Institute of Technology, H. W. Mergler Investigation of Control in Man-Machine Systems with Emphasis on Problems of Remote Manipulation.	66,000
NGR 36-004-013 S 1	Cincinnati, University of, R. J. Kroll Investigation of the Longitudinal Vibrations of Liquid-Fueled Launch Vehicles.	20,000
NGR 36-008-041 S 1	Ohio State University, J. H. Dines and L. B. Roberts Cardiovascular Responses to Environmental Vibrations.	65,000
NGR 36-008-048 S 1	Ohio State University, R. C. Rudduck Theoretical and Experimental Studies of Antennas for Reflectometer Application.	40,000
NsG-448 S 3	Ohio State University, C. Levis Spacecraft Antenna Problems in the Varied Operational Environments of Far-out Space and Atmospheric Re-Entry, Including Considerations of Immersion in a Hot Plasma Sheath and of Omnidirectional Coverage.	45,000
NsG-552 S 2	Ohio State University, C. V. Heer Theoretical and Experimental Investigation of the Measurement of Angular Rotation with Photons.	20,000
NsG 591 S 1	Ohio State University, R. Brodkey Application of an Optical Technique to the Study of the Flow in the Sublayer of Non-Newtonian Fluids.	20,000
Oklahoma:		
NsG-609 S 2	Oklahoma State University, C. A. Dunn Research in Space-Related Sciences and Engineering.	37,500
NsG-609 S 3	Oklahoma State University, C. A. Dunn Research in Space-Related Sciences and Engineering.	75,000
NSR 37-002-045	Oklahoma State University, C. A. Dunn A Pilot Program for Selecting, Editing and Disseminating Engineering and Scientific Educational Subject Matter from NASA Technical Reports.	110,599
Oregon:		
NGR 38-002-020	Oregon State University, R. A. Schmitt Instrumental Activation Analysis of Rare Earths and Other Elements.	49,014
Pennsylvania:		
NGR 39-002-023	Carnegie Institute of Technology, J. L. Swedlow Analysis of Notches and Cracks.	30,000
NsG 270 S 4	Drexel Institute of Technology, P. C. Chou Theoretical Analysis of Liquid Filled Fuel Tanks Impacted by Hypervelocity Particles.	48,660
NGR 39-009-041 S 1	Pennsylvania State University, A. M. Krall Stabilization for Differential Systems, II.	16,829
NGR 39-009-066	Pennsylvania State University, J. P. Hagen Investigation of Solar Flares in the Optical Wavelength Region.	99,642
NGR 39-009-077	Pennsylvania State University, G. M. Faeth Investigation of Near Critical and Supercritical Burning of Fuel Droplets.	19,467
NGR 39-009-077 S 1	Pennsylvania State University, G. M. Faeth Investigation of Near Critical and Supercritical Burning of Fuel Droplets.	25,345

NsG 324 S 4	Pennsylvania State University, E. C. POLLARD Study of the Structure and Function of Living Cells.	170,000
NASr-191 A 5	Pennsylvania, University of, P. S. BALAS Operation of a Power Information Center.	25,000
NsG-335 S 3	Pennsylvania, University of, E. THOROGOOD Molecular Biology of Nitrogen Fixing Nodules of Common Crop Legumes.	50,000
NsG-416 S 3	Pittsburgh, University of, D. HALLIDAY Multidisciplinary Research in Space-Sciences and Engineering.	300,000
R-105 A 3	U.S. Navy-Naval Air Engineering Center, G. L. SANWALD. Turbine Disk Burst Protection Study.	116,000
NGR 39-023-002 S 1	Villanova University, G. C. YEH Kinetic Study of Electrically Activated Reaction Systems.	14,287

RHODE ISLAND:

NGR 40-002-042	Brown University, G. S. HELLER Study of Properties and Application of Solid State Materials at Submillimeter Frequencies.	37,892

SOUTH CAROLINA:

R-124 A 2	U.S. Atomic Energy Commission, S. P. RIDEOUT Investigation of Stress Corrosion Cracking of Titanium Alloys.	72,000

SOUTH DAKOTA:

NONE

TENNESSEE:

NGR 43-001-023	Tennessee, University of, M. W. MILLIGAN Study in Low-Density Gas Dynamics.	23,000
R-104(09) A 3	U.S. Atomic Energy Commission, G. A. ANDREWS A Study of Therapeutic and Accidental Wholebody Irradiation in Man.	300,000
NGR 43-002-015 S 1	Vanderbilt, University of, M. G. BOYCE Application of Calculus of Variations to the Optimization of Multistage Trajectories.	23,000

TEXAS:

NGR 44-003-025	Baylor University, H. S. LIPSCOMB Space Related Biomedical Research.	15,000
NGR 44-003-025 S 1	Baylor University, H. S. LIPSCOMB Space Related Biomedical Research.	259,332
NsG 390 S 3	Baylor University, P. E. KELLAWAY Electrophysiological Correlates of Perception and Performance.	60,503
NASr-198 A 5	Graduate Research Center of the Southwest, K. G. MCCRACKEN. Develop and Evaluate Techniques and Instrumentation for the Measurement of Cosmic Radiation Anisotropies.	61,926
NGR 44-004-039 S 1	Graduate Research Center of the Southwest, W. J. HEIKKILA. Laboratory Evaluation of Ionospheric Probe Measurements.	66,454
NSR 44-004-017 A 3	Graduate Research Center of the Southwest, W. J. HEIKKILA and J. A. FEJER. Technical Appendix for Extended Program Multiple Ionospheric Probe; Comparison of Rocket Borne Probes for Electron Density Measurements.	64,833

NSR 44-004-041 A 1	Graduate Research Center of the Southwest, W. J. HEIKKILA. Develop Payloads for Systemic Study of Auroral Zone Disturbances.	352,706
NGR 44-005-010 S 1	Houston, University of, D. R. TRAYLOR. Metrization of Normal Moore Spaces.	11,237
NsG 673 S 2	Rice University, J. W. FREEMAN. Experimental Investigation of the Methodology and Techniques for Measuring the Relative Abundance of Heavy Ions in the Solar Wind.	121,445
NSR 44-006-023 A 4	Rice University, R. C. HAYMES. Continuation of Sounding Rocket Measurements of Sq Current System.	98,519
NASr 94(02) A 4	Southwest Research Institute, H. J. KORP. Evaluation and Bringing to Industrial or Commercial Fruition, Technological Developments Resulting from the Nation's Space Effort.	104,850
NASr 94(09)	Southwest Research Institute, R. W. WARE. Assist in Accomplishing the Transfer of Applicable Science and Technology from NASA's R & D Program into the Bio-Medical Field.	86,517
NGR 44-012-049	Texas, University of, C. L. COATES. Structure Theory for the Realizations of Finite State Automata.	31,661
NsG-604 S 2	Texas, University of, W. R. COX. Continuation of Studies Related to the Use of Models to Predict Behavior of Spacecraft on Impact with Soils.	62,000

UTAH:

NGR 45-001-011 S 1	Brigham Young University, D. E. JONES. Analysis and Interpretation of Magnetic Field Measurements Between Earth and Mars Performed by the Mariner IV Magnetometer.	20,561
NGR 45-002-008	Utah State University, F. B. SALISBURY. The Response of Higher Plants to Ultraviolet Light and Other Stress Factors.	28,500

VERMONT:

NONE

VIRGINIA:

NGR 47-006-025	William and Mary, College of, G. S. OFEIT. Investigation of Gas Temperature Measurements Using Ultraviolet Excitation.	24,720
NGR 47-006-027	William and Mary, College of, M. A. PITTMAN. Investigation of Spectral Properties of Ultraviolet Gratings.	36,925
NGR 47-002-004 S 1	Medical College of Virginia, F. R. O'FOGHLUDA. Investigation of Total Energy Absorption in Omnidirectional Photon and Particle Fluxes.	27,775
NGR 47-002-005 S 1	Medical College of Virginia, W. T. HAM. Radiation Hazards to the Eye.	51,845
NGR 47-004-006 S 3	Virginia Polytechnic Institute, J. A. JACOBS and F. W. BULL. Multidisciplinary Space-Related Research in Engineering and the Physical and Life Sciences.	175,000
NGR 47-005-066	Virginia, University of, L. W. FREDRICK. Broad and Specific Studies in Astronomy and in Related Scientific and Engineering Fields.	16,719

WASHINGTON:		
NGR 48-002-010 S 1	Washington, University of, R. G. JOPPA — Experimental and Theoretical Investigation of Wind Tunnel Geometry, Emphasizing Factors Pertinent to V/STOL Vehicle Testing.	43,778
NGR 48-002-033	Washington, University of, P. W. HODGE — Study of Interplanetary Dust.	40,000
NGR 48-002-035	Washington, University of, W. H. RAE — An Experimental Investigation of Wind Tunnel Test Limits for V/STOL Type Vehicles in Wind Tunnels with Curved Walls.	56,658
NsG 401 S 4	Washington, University of, R. J. BOLLARD — An Analytical and Experimental Study, Using Photoelastic Methods, to Establish a Procedure for Stress Analysis of a Viscoelastic Model Subjected to Transient Temperature and Time-Dependent Loading.	42,624
NsG(F) 35	Washington, University of, R. J. BOLLARD — Construction of Aerospace Research Laboratory.	1,500,000
WEST VIRGINIA:		
NGR 49-001-012 S 1	West Virginia University, E. C. CARTER — Study of the Economic Feasibility and Impact of Vertical or Short Take-Off and Landing Aircraft for the Appalachian Region.	16,761
NsG 533 S 3	West Virginia University, J. C. LUDLUM — Space-Related Studies in the Physical, Life, and Engineering Sciences.	50,000
WISCONSIN:		
NGR 50-002-044 S 1	Wisconsin, University of, W. L. KRAUSHAAR — Research in Cosmic and Solar Physics.	50,000
NGR 50-002-051	Wisconsin, University of, J. R. CAMERON — Applications of the Direct Photon Absorption Technique for Measuring Bone-Mineral Content, In Vivo.	23,078
NsG 439 S 1	Wisconsin, University of, E. N. CAMERON — Quantitative Investigation of the Mineralogy and Petrography of Iron Meteorites and Opaque Minerals in Returned Lunar Samples.	38,000
NsG 618 S 2	Wisconsin, University of, A. D. CODE — Investigations and Studies of Ultraviolet Stellar Spectra and Associated Instrumentation.	140,000
NsG(F) 34	Wisconsin, University of, V. SOUMI — Construction of Research Laboratory Facilities Housing the Space Sciences and Engineering Center of the University of Wisconsin.	1,700,000
WYOMING:		
NONE		
FOREIGN:		
NGR 52-046-001 S 1	Innsbruck University, F. CAP — Solution of Two Problems connected with Space Research by means of Lie Series Representation.	5,000
NGR 52-059-001 S 1	McMaster University, A. B. KRISTOFFERSON — A Study of Attention and Psychological Time.	28,378
NSR 52-112-001	Queen's University, F. J. SMITH — Calculations of Higher Order Collision Integrals for use in the Determination of Transport Coefficients of High Temperature Gases.	8,000

Appendix R

Institutions Currently Participating in NASA's Predoctoral Training Program

(December 31, 1966)

Adelphi University
Alabama, University of
Alaska, University of
Alfred University
Arizona State University
Arizona, University of
Arkansas, University of
Auburn University
Baylor University
Boston College
Boston University
Brandeis University
Brigham Young University
Brooklyn, Polytechnic Institute of
Brown University
California Institute of Technology
California, University of, at Berkeley
California, University of, at Los Angeles
California, University of, at Riverside
California, University of, at San Diego
California, University of, at Santa Barbara
Carnegie Institute of Technology
Case Institute of Technology
Catholic University of America
Chicago, University of
Cincinnati, University of
Clark University
Clarkson College of Technology
Clemson University
Colorado School of Mines
Colorado State University
Colorado, University of
Columbia University
Connecticut, University of
Cornell University
Dartmouth College
Delaware, University of
Denver, University of
Drexel Institute of Technology
Duke University
Duquesne University
Emory University
Florida State University
Florida, University of
Fordham University
George Washington University
Georgetown University
Georgia Institute of Technology
Georgia, University of
Hawaii, University of
Houston, University of
Howard University
Idaho, University of
Illinois Institute of Technology
Illinois, University of
Indiana University
Iowa State University
Iowa, University of
Johns Hopkins University
Kansas State University
Kansas, University of
Kent State University
Kentucky, University of
Lehigh University
Louisiana State University
Louisville, University of
Lowell Technological Institute
Maine, University of
Marquette University
Maryland, University of
Massachusetts Institute of Technology
Massachusetts, University of
Miami, University of
Michigan State University
Michigan Technological University
Michigan, University of
Minnesota, University of
Mississippi State University
Mississippi, University of
Missouri, University of
Missouri, University of, at Rolla
Montana State University
Montana, University of
Nebraska, University of
Nevada, University of
New Hampshire, University of
New Mexico State University
New Mexico, University of
New York, The City University of
New York, State University of, at Buffalo
New York, State University of, at Stony Brook
New York University
North Carolina State
of the University of North Carolina
North Carolina, University of
North Dakota State University
North Dakota, University of
Northeastern University
Northwestern University
Notre Dame, University of
Ohio State University
Ohio University
Oklahoma State University
Oklahoma, University of
Oregon State University
Pennsylvania State University
Pennsylvania, University of
Pittsburgh, University of
Princeton University
Purdue University
Rensselaer Polytechnic Institute
Rhode Island, University of

Rice University
Rochester, University of
Rutgers—The State University
St. Louis University
South Carolina, University of
South Dakota, University of
Southern California, University of
Southern Illinois University
Southern Methodist University
Southern Mississippi, University of
Stanford University
Stevens Institute of Technology
Syracuse University
Temple University
Tennessee, University of
Texas A&M University
Texas Christian University
Texas Technological College
Texas, University of
Toledo, University of
Tufts University
Tulane University
Utah State University
Utah, University of
Vanderbilt University
Vermont, University of
Villanova University
Virginia Polytechnic Institute
Virginia, University of
Washington State University
Washington University (St. Louis)
Washington, University of
Wayne State University
West Virginia University
Western Reserve University
William and Mary, College of
Wisconsin, University of
Worcester Polytechnic Institute
Wyoming, University of
Yale University
Yeshiva University

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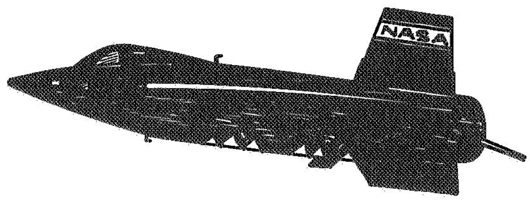
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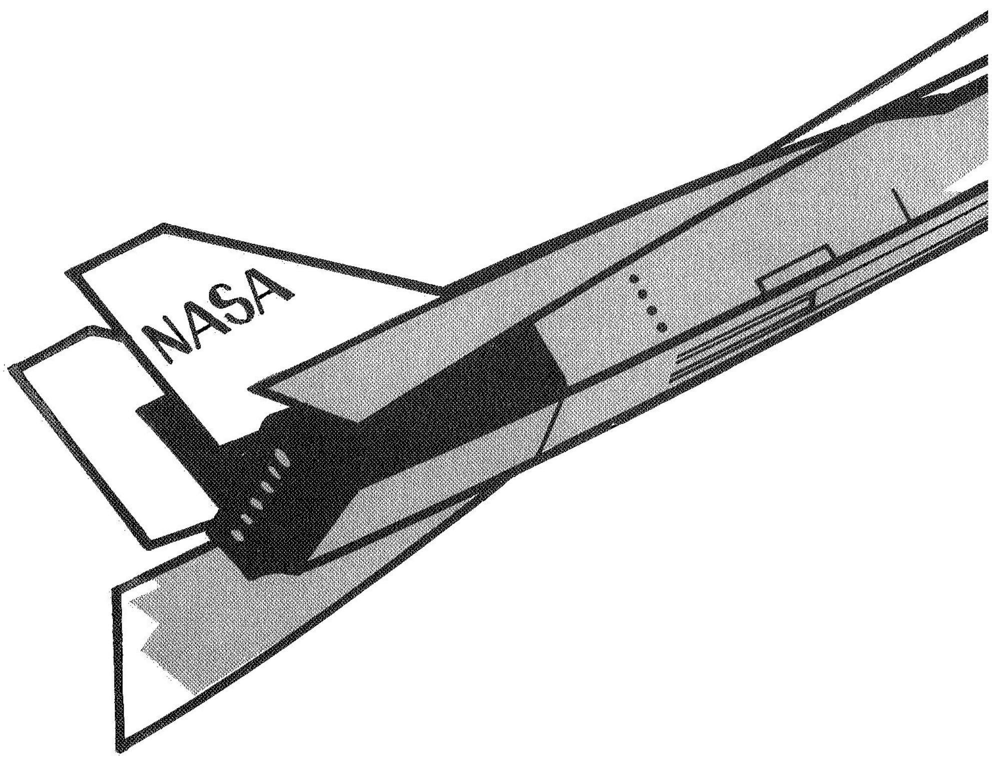
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